

Adding emotional stressors to training in simulated cardiopulmonary arrest enhances participant performance

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OBJECTIVES Advanced cardiac life support (ACLS) skills tend to degrade over time. There is mounting evidence that high-fidelity simulation (HFS) is advantageous to teaching ACLS. The aspects of HFS that enhance learning are not entirely clear, but the anxiety generated by a scenario may enhance retention through well-established learning pathways. We sought to determine whether an HFS with added emotional stress could provoke anxiety and, if so, whether or not participants learning ACLS would demonstrate better written and applied knowledge retention 6 months after their initial course.

METHODS Twenty-five student volunteers from Year 1 and 2 at Mount Sinai School of Medicine were randomly assigned to a control group or an emotional content (EC) group for a sudden cardiac death management course. All subjects were monitored for heart rate and were assessed using the State-Trait Anxiety Inventory. Control group participants experienced an HFS in which actors were not scripted to add stress, whereas EC group participants were exposed to an emotionally charged environment using the same actors.

RESULTS Participants across the two groups were well matched by resting heart rates, baseline anxiety and prior ACLS knowledge. The EC group participants experienced greater anxiety than controls (mean state anxiety score: 35.0 versus 28.2 [$p < 0.05$]; average heart rate [HR]: 94.6 bpm versus 72.9 bpm [$p < 0.05$]; maximum HR: 120.8 bpm versus 95.3 bpm [$p < 0.05$]). Six months later, written test scores were similar, but the EC group participants achieved higher practical competency examination ('mega code') scores than controls (32.5 versus 25.0; $p < 0.05$). Independent *t*-tests and Spearman rank coefficients were employed where applicable.

CONCLUSIONS Simulation with added emotional stressors led to greater anxiety during ACLS instruction but correlated with enhanced performance of ACLS skills after this course. The quantitative and qualitative values of added stressors need further exploration, but these values represent important variables in simulation-based education.

Medical Education 2010; **44**: 1006–1015
doi:10.1111/j.1365-2923.2010.03775.x

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INTRODUCTION

Sudden cardiac death is a serious medical problem, which, despite a long history of research into the subject, tends to be poorly managed by hospital responders.^{1,2} Knowledge of advanced cardiac life support (ACLS) is required for hospital-based doctors as a part of privileging procedures for most institutions. In general, completion of an American Heart Association (AHA)-sanctioned course with bi-yearly renewal is considered satisfactory evidence of written and practical (applied) ACLS knowledge.³ Despite this renewal schedule, studies have consistently demonstrated a rapid decay in practitioners' ACLS skills.^{4,5} As most clinicians do not resuscitate patients on a regular basis, several authors have suggested more frequent practice and re-certification as a way to enhance retention.^{6,7} Although frequent practice is likely to be one key to mastery of such knowledge and skills, the ACLS learning environment may also affect retention, recall and later performance in an actual cardiopulmonary arrest.

High-fidelity simulation (HFS) using physiological model-driven, life-sized manikins with measurable vital signs and other 'real' attributes can create 'true-to-life' experiences for learners. When coupled with simulated hospital personnel and patient family members, believable scenarios and familiar locales may be emulated (full environment simulation [FES]). Studies focusing on deliberate practice and HFS compared with traditional training have shown promising results regarding retention of ACLS⁸⁻¹¹ and other rare and critical event management skills.¹²

Although FES may be educationally advantageous, it is often more costly, complex and time-consuming. Educators engaged in simulation seek to reproduce clinical scenarios with good face validity, but realism of clinical environments and patient conditions may not be the elements that make FES an effective learning environment. Evidence from both the aviation and anaesthesia literature suggests that these elements alone may not be advantageous when compared with simpler, less expensive, screen-based simulators.^{13,14} For this reason, Beaubien and Baker¹⁵ aptly note that the literature is in its infancy regarding a demonstrative link between fidelity and the effectiveness of training, yet many assume that more realism equates to better simulation.

Rehmann *et al.*¹⁶ developed a typology identifying three key components of simulation that determine

fidelity: equipment fidelity; environment fidelity, and psychological fidelity (Fig. 1).

The elements that favour learning in simulation are not entirely known, although they most certainly involve the interplay of these components. Many have suggested that the major parameter needed to implement an HFS is the fidelity imparted by cues from manikins (i.e. equipment fidelity).^{17,18} This fails to acknowledge the fidelity of the scenario script itself and may limit the view of simulation as an educational intervention reliant on a device to ensure fidelity and presumed effectiveness. In fact, events in a scenario that increase levels of anxiety may play key roles in enhancing trainee knowledge and skills retention. Emotional stress can enhance one or more memory stages, including the creation of new memories (encoding), the persistence of these memories (consolidation) and the final access to stored information (retrieval). Compared with typical memories, which rely upon hippocampal pathways, events associated with emotional stressors and anxiety are fixed in memory via pathways that involve the amygdala and tend to be less vulnerable to extinction and, therefore, enhance retention.^{19,20}

Our group has observed that trainees recall details of scenarios in which they felt they had failed or scenarios that involved a highly stressful setting more easily than contexts in which they experienced less anxiety. We added stressors to an abbreviated HFS ACLS course in order to generate measurable anxiety amongst medical student participants. We chose ACLS because a formalised set of testing instruments exists for this topic and we chose medical students with no exposure to ACLS so that their performance would be unlikely to be affected by experience. We

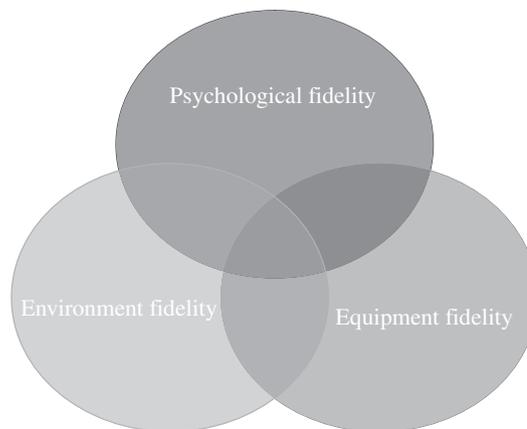


Figure 1 Typology of simulation fidelity

sought to determine whether increased anxiety caused by scripted stressors would correlate with enhanced retention of ACLS knowledge and skills.

METHODS

Study design

Study approval was obtained from the Mount Sinai School of Medicine Programme for the Protection of Human Subjects, and medical students in Years 1 (MS1) and 2 (MS2) at Mount Sinai School of Medicine were contacted via e-mail (Appendix S1). The first 25 respondents were enrolled in this study and randomised to a control group or an 'emotional content' (EC) group (Fig. 2). All participants had active basic life support (BLS) certification, but none had taken ACLS courses in the past. The demographics of the two groups are presented in Table 1.

The study was divided into three phases: a didactics phase; a code management phase, and an assessment phase. In the first phase, all participants attended a 4-hour group session which covered sudden cardiac death management content adapted from the AHA ACLS course, as well as the skills performed during a code (i.e. chest compressions, defibrillation, intubation). The content of this session was developed with and evaluated by the chair of our institution's cardiopulmonary resuscitation (CPR) committee. Prior to this session, students completed a 50-item quiz (pre-test) created using selected items from the ACLS certification examination. Items specifically addressing BLS and malignant arrhythmia management (i.e. pulseless rhythms and myocardial infarction) were chosen. Students completed the 20-item trait portion of the State-Trait Anxiety Inventory (STAI), used to measure anxiety in adults.²¹ The trait subscale measures baseline anxiety and the state subscale measures current anxiety (how the partici-

Table 1 Summary of group characteristics for completers only in the emotional content (EC) and control groups

	EC group (<i>n</i> = 13)	Control group (<i>n</i> = 12)
Completers, <i>n</i>	10	10
Mean age, years (SD)	24.3 (2.2)	23.5 (1.6)
Male, <i>n</i> (%)	4 (40)	7 (70)
Year 1, <i>n</i> (%)	7 (70)	7 (70)

SD = standard deviation

pant feels 'right now'). The range of scores is 20–80, with higher scores indicating greater anxiety.

Participants returned individually to the Mount Sinai Medical Center Department of Anaesthesiology Simulation Center²² for their 60-minute code management session, at 1–2 weeks after the didactic session. The control group was to experience an HFS without any deliberately scripted stressors. The EC group participants were to experience several pre-planned stressors during their sessions. All subjects recorded their resting heart rates in the week prior to the session and provided this information to a study group member. Each participant was oriented to the simulated environment and then fitted with a heart rate monitor.

The following case was presented verbally to all participants, regardless of group assignment:

'A 65-year-old man with a history of hypertension, obesity, a sedentary lifestyle and long-term tobacco use is recovering from surgery, a hemi-colectomy, which had been performed earlier in the day. He is currently in the recovery room. A nurse pages you [the participant] because the patient has developed shortness of breath.'

The simulator (METI HPS; Medical Education Technologies, Inc., Sarasota, FL, USA) was programmed with the following baseline parameters: heart rate 108 bpm; blood pressure 105/65 mmHg; oxygen saturation 96% on room air; respiratory rate 22 breaths per minute, and ST segment depressions on the monitor. The patient then lost consciousness and began to have frequent premature ventricular contractions (PVCs), which degraded into unstable but pulsatile ventricular tachycardia (v-tach),

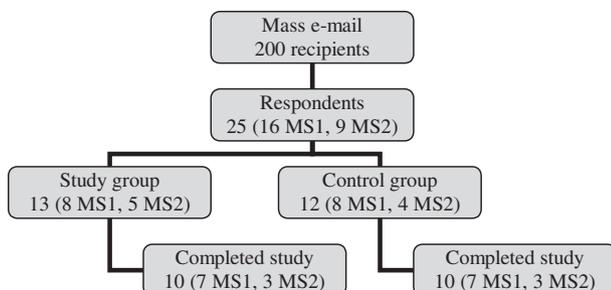


Figure 2 Enrolment scheme. MS1 = Year 1 medical students; MS2 = Year 2 medical students

followed by pulseless v-tach, ventricular fibrillation (v-fib), asystole and pulseless electrical activity (PEA). The scenario took approximately 30 minutes to unfold. Participants in each group entered the laboratory alone (i.e. everyone else in the laboratory was a confederate) and played the part of a surgical resident functioning as code (cardiopulmonary arrest) leader. Actors played the roles of nurse, intern and family member and were the agents of 'emotional content' where specified in the scenario. Actors ('confederates') were expected to follow the scenario scripts closely. Two separate scripts were developed, of which one was used with controls and the other was used with EC group members. Confederates were told which script to use before each session, were asked to perform scripted actions and statements in a consistent way for all sessions and were trained in the delivery of the control and EC scenarios. Participants in the EC group all received the same scripted interventions (i.e. stressors) in the same order and on the same timeline (e.g. towards the end of the scenario before the last rhythm change, the intern knocks out the intravenous line). Table 2 displays a comparison of the control versus EC group scenarios.

All participants were asked to verbalise their diagnosis and treatment at each point in the scenario and to perform necessary interventions (e.g. chest compressions, intubation) once before the actual scenario was started to ensure these tasks were reviewed. Participants in each group could ask the facilitator of their session for assistance at any point in the scenario if they were unsure of the diagnosis or treatment indicated, but were expected to be at the foot of the bed directing the code as much as possible. Participants in both groups were encouraged to manage the case with their 'hands free' when possible so they could direct the team more effectively, although if they chose to perform an intervention on their own, they were assisted in doing so. The nurse and intern were available to deliver drugs, manage the airway and perform chest compressions as the participant directed.

After the skills session, all participants took a 32-item quiz (post-test) and the 'state' portion of the STAI. The multiple-choice item quiz was adapted from the ACLS certification examination and focused on ACLS algorithm application, management and treatment of malignant arrhythmias and BLS principles. All participants were then debriefed with a focus on the conduct of the resuscitation and adherence to BLS and ACLS algorithms. The elements of effective team leadership and communication during resuscitation

were discussed for both groups. The simulation team at Mount Sinai does not incorporate protocolised debriefings because of the diverse nature of its programmes. However, the 'good judgement' principles outlined by Rudolph *et al.*²³ were used for all debriefings. In this study, the debriefer was well versed in these principles and had been giving formalised debriefings at the medical student level for 4 years. The only difference in the debriefings concerned the discussion of the patient outcome and the stressful portions of the case encountered by the EC group participants.

The assessment phase occurred 6 months after the skills phase. All participants returned to the simulator for their final practical (mega code) and written tests. The day before this session, participants were informed that they would be managing a code in the simulator and that they would receive little help during the scenario. All participants encountered a similar scenario, as they had in the skills session. The setting was that of an emergency room. This time the patient experienced the sudden onset of shortness of breath after shovelling snow at home. Three study group members were available to perform the necessary interventions and to administer drugs during the scenario. No actor portraying a family member was present. No emotional stressors, *per se*, were inserted into this final scenario and no cognitive assistance was available from the instructors. After the session, participants completed a 32-item quiz (final test). All sessions were videotaped and later reviewed and scored (Appendix S2) by two independent raters, who were attending anaesthesiologists certified in ACLS. The assessment tool was developed using ACLS mega code score sheets, validated internally using participants with active ACLS certification and tailored to the study goals and objectives. Reviewers were blinded to group assignments.

Participants were asked to assess their perceived ability to manage a code in the future on a scale of 1–5 (self-efficacy score), where 1 = not at all able, 3 = moderately able and 5 = completely able. They were also asked to indicate the degree to which they felt 'the scenarios encountered were good recreations of what (they imagined) a real code to be like' on a rating scale of 1–5 (realism score), where 1 = not at all, 3 = close to real code and 5 = exactly like a real code.

Statistical analysis

Group characteristics and scores were compared using unpaired Student's *t*-tests. Agreement on the

Table 2 Comparison of skills laboratory experiences for the emotional content (EC) and control groups

Factor	Control group	EC group	Notes
Environment Simulator	Sim Lab METI HPS	Same Same	Identical lab Identical monitors in place for both groups (ECG, NIBP, pulse oximeter), all features of METI HPS enabled
Scenario	ACLSTEST	Same	Developed for this study Total time if left uninterrupted: 26 minutes Vital signs: heart rate 108 bpm; blood pressure 105/65 mmHg; oxygen saturation 96% on room air; respiratory rate 22 breaths per minute Succession of arrhythmias in scenario: sinus tachycardia with ST depressions, frequent PVCs, unstable v-tach, pulseless v-tach, v-fib, asystole, PEA
Scenario facilitator Participant role	Primary author Code leader	Same Same	In both groups, participants were instructed to direct the code and remain 'hands-free'
Number of confederates Instruction during scenario	3 (nurse, intern, family member) As needed by facilitator	3 (nurse, intern, distraught family member) Same	If a participant could not correctly identify an arrhythmia or necessary intervention before the next arrhythmia was set to appear, the instructor paused the scenario to allow for teaching
Script components Family member	Upon loss of consciousness he shakes the patient to wake him The nurse asks him to leave and he says: 'Please take good care of my dad' as he leaves	Upon loss of consciousness he enters the room and repeatedly asks: 'What's wrong? What's happening to my dad?' Shakes simulator, tearfully saying: 'Dad!' As the code progresses, he asks the participant: 'What are they doing to him?'	
Intern	After loss of consciousness he asks: 'How can I help?' Performs actions as specified by participant	After loss of consciousness, he shouts: 'This is my patient, we have to save him!' Performs actions as specified by participant but suggests they shock asystole each time it is recorded	
Nurse	Asks: 'How can I help?' as code starts Performs requested actions	Repeatedly says: 'Oh no, he's going to die!' Asks the participant to pronounce the patient dead at the end of the scenario and to talk to the family member who is waiting outside At the end of the session, states: 'We're all going to get sued!'	In the control group, when the scenario reached completion the facilitator told the participant that the exercise had finished, but death was not pronounced EC group participants were required to pronounce death and explain to the family member that the patient had expired
Debriefing Facilitator Duration Content	Primary author 15 minutes The debriefing utilised video of the encounter and focused specifically on adherence to the ACLS algorithms and effective leadership and communication during the crises If the participant asked whether he or she had 'killed' the patient, the participant was told the patient was programmed to expire	Same Same As for the control group Also discussed pronouncement of death and explanation of bad news to the patient's family as well as the numerous stressful events they perceived Participants were told that the scenario was not designed to end in failure and that the patient could have been saved	

ACLS = advanced cardiac life support; PVCs = premature ventricular contractions; v-tach = ventricular tachycardia; v-fib = ventricular fibrillation; PEA = pulseless electrical activity

two raters' performance scores was estimated by the Spearman rank correlation coefficient, and further assessed using the Wilcoxon signed rank test. Internal consistency of the evaluation instrument was determined by Cronbach's α . The Wilcoxon rank sum test was used to compare the average of the two raters' total performance scores between groups.

RESULTS

The two groups were well matched in terms of the demographic characteristics of all randomised persons and those of completers only (Table 1). Resting heart rates and trait anxiety scores were comparable. Markers of induced anxiety (scenario heart rates and state anxiety scores) differed significantly between the groups, whether comparing all randomised persons or completers only (Table 3). Figure 3 shows samples of heart rate data for an EC and a control group participant.

The skills laboratory scenario duration was similar between groups (32.4 minutes versus 32.1 minutes for the control group versus the EC group; $p = 0.57$). The number of pauses for teaching during the scenarios was also similar (4.2 pauses versus 4.5 pauses for the control group versus the EC group; $p = 0.19$). Written and mega code examination data are reported in Table 4. No significant differences were noted between groups for the written examinations before, during or after completion of the course. Mega code performance scores 6 months after the initial course were highly correlated between faculty raters, with a Spearman rank correlation coefficient for the total scores of 0.97. The median differences in total score between raters ranged from -4 to $+2$, with a median of 0.0 (Wilcoxon test, $p = 0.16$). The EC group scored significantly higher on the performance assessment.

Table 3 Comparison of mean heart rates and mean State-Trait Anxiety Inventory scores between the emotional content (EC) and control groups

	EC group	Control group	p-value
Resting heart rate, bpm	70.5	71.4	0.71
Average heart rate, bpm	94.6	72.9	< 0.0001
Maximum heart rate, bpm	120.8	95.3	< 0.0001
Trait anxiety score	35.5	33.9	0.56
State anxiety score	35.0	28.2	0.004

Resting heart rates were self-reported by participants. Average and maximum heart rates were recorded during individual skills sessions. Trait anxiety scores were collected with the pre-test data before the didactic portion of the course. State anxiety scores were recorded immediately after the individual skills sessions

Self-efficacy scores were similar between the two groups, with mean ratings of 3.7 and 3.8 ($p = 0.61$) for control and EC group participants, respectively. Realism scores did not differ significantly, with mean ratings of 4.8 and 4.5 ($p = 0.22$) for control and EC group participants, respectively.

DISCUSSION

Advanced cardiac life support skills tend to degrade over time.^{4,5} More efficient educational interventions that improve the retention of these skills are needed. We found that adding stressful dialogue and actions into a standardised HFS-based ACLS teaching scenario increased the level of anxiety over that experienced by participants not exposed to stressors. Increased subject anxiety experienced in this cardiac arrest management teaching session

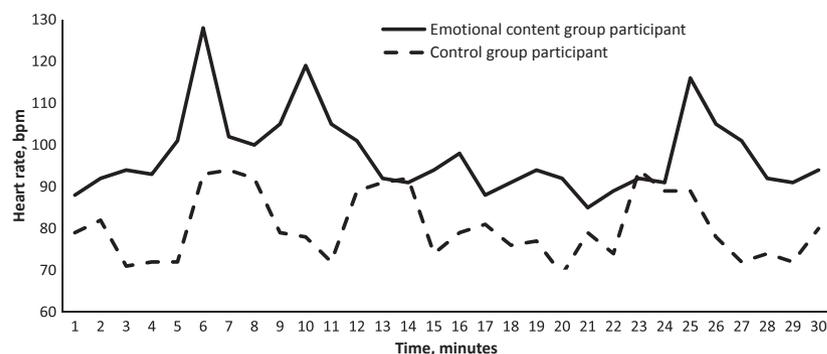


Figure 3 Sample heart rate data for an emotional content group and a control group participant

Table 4 Comparison of scores of knowledge and performance between the emotional content (EC) and control groups

	EC group	Control group	p-value
Pre-test score*	0.37 (0.34–0.40)	0.41 (0.37–0.45)	0.41
Post-test score*	0.73 (0.71–0.75)	0.75 (0.74–0.76)	0.28
Final score*	0.74 (0.71–0.77)	0.74 (0.71–0.77)	0.95
Performance score [†]	32.5	25.0	0.0003

* Mean values (95% confidence interval) are shown for the pre-test, post-test and final scores

[†] Median of the two raters' average performance scores. Participants took identical multiple-choice tests with 50 questions on the pre-test and 32 questions on both the post- and final tests. Two attending anaesthesiologists blinded to group assignment determined performance scores

correlated with increased ACLS mega code scores 6 months later. Regardless of group assignment, all participants improved ACLS knowledge scores from pre-test levels, which is consistent with other findings.^{8–11} Participants in the EC group, however, showed significantly better practical application of knowledge. These results are consistent with our hypothesis that the addition of emotional stressors capable of increasing participant anxiety is educationally advantageous.

To our knowledge, we are the first to demonstrate that scripted emotional stressors in HFS increase participant anxiety and long-term retention of applied knowledge. As the final written examination scores did not differ between groups, this suggests that added emotional stressors had a greater effect upon practical knowledge retention and application, as measured by the mega code. Both of our participant groups were exposed to HFS, according to accepted standards,¹⁸ yet better educational outcomes were achieved in the EC group. No additional material resources were needed to attain this outcome.

It is unknown to what extent stress is beneficial or detrimental in knowledge acquisition and retention. Stress represents a divergence between the demands on an individual and that individual's capabilities. It may lead to anxiety (i.e. a state of uneasiness or worry).²⁴ Reactions to stressors will vary among

individuals and are especially prominent in clinical crises, in which individual²⁵ and team performance may be impeded.²⁶ In a survey, anaesthesia trainees reported experiencing stress and anxiety during simulations, but that this improved their learning and clinical performance.²⁷ Conversely, a self-report study of students in a high-acuity nursing simulation course demonstrated that anxiety hampered learning.²⁸ Neither study assessed validated measures of stress or anxiety or measured educational outcomes. Although stress can impair memory retrieval in a crisis, a non-medical investigation found that intense stress was associated with higher decision-making performance scores.²⁹

The results of the current investigation contrast with much existing literature in which stress and anxiety have been associated with impaired learning. The few simulation-based studies in which anxiety was measured involved expert participants and examined performance, not the retention or practical application of new knowledge.^{30–32} High-fidelity simulation did not improve the retention of knowledge and skills in one study, but, again, knowledge of how much stress was inserted by actors through script or action, and validated measures of stress and anxiety were lacking.³³

Simons and De Jong³⁴ assert that 'becoming an active learner is a difficult and stressful process'. Negative emotions, such as anxiety or frustration, are generally framed as de-motivating and diversionary, shifting attentional resources away from educational activities³⁵ and hindering retention and performance, especially in novice learners whose cognitive demands are high.³⁶ The de-motivating aspect of anxiety also manifests in a negative relationship between anxiety and self-efficacy throughout the psychological literature,^{37,38} and excessive stress during a scenario may be detrimental to performance even amongst experts.³⁹ Variation and lack of precise control of the degree of stress in previous investigations may partially explain why those findings differed from results in this work.

Our results suggest that there is a level of stress and anxiety that is possibly beneficial for knowledge retention and that does not hurt self-efficacy. There is probably a range of stress that is optimal for learning, and a range that induces so much anxiety that it compromises an educational experience. Most practitioners learn ACLS in courses in which management skills are taught using low-fidelity simulation (LFS) and no specific measurable 'dose' of stress. This is

inconsistent with reality, in which sudden cardiac death resuscitations often occur in hectic, emotionally charged settings and often have poor outcomes. It is logical that experiential, active learning should be beneficial to participants learning cardiac arrest management. However, 'experiential' is generally taken to imply a scenario involving good equipment and environment fidelity. The remarkably divergent findings in the existing literature suggest that future investigations should use more rigorously controlled scenario scripts, specific and measurable degrees of stress, and validated tools to assess the resultant anxiety and learning that may occur.

The current investigation is limited in several respects. Participants were junior medical students with no appreciable clinical experience, which may have had an effect on their ability to perform during the mega code and to rate the realism of the scenario. The voluntary nature of the study may have introduced selection bias. The absence of more experienced practitioners and the small sample size are also limiting factors, despite the fact that statistical significance was achieved for several key outcomes.

We did not measure data to explain the mechanisms by which enhanced learning occurred. It is possible, for example, that heightened anxiety experienced by the EC group participants prompted them to pursue further study in the time between the simulation session and the final assessment. Even in the absence of anxiety, feeling 'responsible' for a simulated patient death may have also prompted motivated students to study independently or may have enhanced their retention of knowledge. We did not measure whether students had any additional exposure to code situations in the time between training and their final assessment, although, given their MS1 and MS2 levels, we thought this to be highly unlikely.

Most simulation-based studies use participant reports of realism and self-efficacy as markers of scenario face validity and effectiveness.⁴⁰ Our participant groups gave similar self-efficacy and realism scores. Both groups encountered the same scenario except for small nuances in the actors' scripts. They did not perceive differences in the realism of the scenario. This limits the likelihood that the control group inadvertently experienced LFS rather than the intended HFS. Measurements of anxiety may be prone to error if participants do not answer truthfully. Still, the reliability⁴¹ and validity⁴² of the STAI

have been reported extensively and heart rate data seem to support STAI data in this study.

We sought to determine whether anxiety secondary to scripted stressors would enhance knowledge and skills retention in an ACLS course. We found that the addition of emotional stressors did induce anxiety and was associated with improved long-term practical knowledge application in novice trainees. Data regarding the effects of stress on general educational outcomes are inconsistent, and there are very limited data in the medical simulation literature. The current investigation suggests that there are levels of anxiety that enhance learning in the HFS environment, even amongst novice participants. Emotional stress, therefore, may represent an important variable that affects the outcomes of simulation-based medical education.

Contributors: SD, EOB, JHS, DLR and AIL contributed to the study conception and design. SD, EOB, TJM, CB and AIL contributed to the acquisition of data. All authors contributed to the analysis and interpretation of the data, and to the drafting and critical revision of the article. All authors approved the final version of the manuscript.

Acknowledgements: the authors wish to acknowledge the medical students who made this study possible and the Department of Anaesthesiology at Mount Sinai Medical Center, New York, for its support of this endeavour.

Funding: this study was supported by intramural funding from Mount Sinai School of Medicine, Department of Anaesthesiology.

Conflicts of interest: none.

Ethical approval: this study was approved by the Mount Sinai School of Medicine Department of Protection of Human Subjects.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article.

Appendix S1. Enrolment e-mail.

Appendix S2. Final skills assessment sheet.

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Received 10 April 2010; editorial comments to authors 26 May 2010; accepted for publication 10 June 2010