Veterinary high-stakes immersive simulation training with repeat practice following structured debriefing improves students’ ability to cope with high-pressure situations.

Citation for published version:
Pollock, K, MacKay, J, Hearns, S, Morton, C & Pollock, P 2024, 'Veterinary high-stakes immersive simulation training with repeat practice following structured debriefing improves students’ ability to cope with high-pressure situations.', *Simulation in Healthcare*. https://doi.org/10.1097/SIH.0000000000000771

Digital Object Identifier (DOI):
10.1097/SIH.0000000000000771

Document Version:
Peer reviewed version

Published In:
Simulation in Healthcare

Veterinary high-stakes immersive simulation training with repeat practice following structured debriefing improves students' ability to cope with high-pressure situations.

Dr. Kristina Pollock MVB, PhD, CertSAS, SFHEA, MRCVS, Director of Clinical and Simulation Teaching Kristina.pollock@ed.ac.uk

Dr. Jill R.D. MacKay MSci, PhD, Senior Lecturer in Veterinary Medical Education

*Dr. Stephen Hearns MB ChB, FRCEM FRCS FRCP FRGS DIMC DRTM Consultant in Emergency Medicine

Dr. Carolyn Morton BVMS, MVM, MRCVS, Lecturer in Professional and Clinical Skills

**Professor Patrick J Pollock BVMS, PhD, Dip ECVS, FHEA, FRCVS. Professor of Veterinary Surgery and Remote and Rural Medicine

Royal (Dick) School of Veterinary Studies, University of Edinburgh, Easter Bush, Midlothian, EH25 9RG, Scotland (address for correspondence)

** Glasgow Equine Hospital and Practice, School of Biodiversity, One Health & Veterinary Medicine, University of Glasgow, Glasgow, G611QH, Scotland

* Emergency Medical Retrieval Service, ScotSTAR, Hangar B, 180 Abbotsinch Road, Paisley, PA3 2RY, Scotland

Abstract

Introduction. Immersive simulation is used increasingly in medical education, and there is increasing awareness of the impact of simulation scenarios on emotional state and cognitive load and how these impact learning[1]. There is growing awareness of the requirement to equip veterinarians with skills for managing high-pressure environments and provide training on human factors. *Methods.* Veterinary students participated in a high-fidelity immersive simulation of a road traffic collision involving multiple casualties. The students took part in the same simulation twice, the second time following a debrief. Each participant's emotional state and cognitive load were assessed after participating in each simulation. Each participant was asked to score the effect of pressure on their performance. *Results.* 125 students participated and demonstrated a higher cognitive load with more positive emotional states during the second scenario, following the completion of a structured debrief and discussion focusing on pressure relief techniques (cognitive load -$\bar{\mu}$Scenario run 1 = 4.44 ± 1.85 (SD), $\bar{\mu}$Scenario2 = 5.69 ± 1.74 (SD). The majority of participants described being in the low-performance state of frazzle (63%) during the first scenario compared to a majority that described being in the high-performance state of flow (61%) during the second. *Conclusion.* Immersive simulation scenarios, with structured debriefing, may allow the measurement of emotional state and cognitive load in participants. Furthermore, this study suggests that curriculum training in human factors and pressure relief techniques, coupled with immersive simulation and debrief, may improve future performance in high-stakes and high-pressure scenarios.

Introduction

Veterinary educators are interested in the performance of veterinarians in high-stakes situations and its broader implications for resilience, and how we train veterinary students for sustainable "operational deployment" beyond their time at university.[2] Increasingly, veterinarians work as part of a multidisciplinary group with first responders attending incidents involving animals and people, including at road traffic collisions (RTCs), major incidents, and following natural disasters.[3] Resilience has been highlighted as a core day-one competency for veterinary graduates by the Royal College of Veterinary Surgeons (RCVS) and American Veterinary Medical Association (AVMA).[4]

Historically, immersive simulation has been used as a teaching tool in aviation, the military, aeronautics and space, the nuclear and oil industries, and, more recently, in healthcare training. Immersive simulation is now a core component of medical undergraduate and postgraduate training, offering learners the opportunity to practice an activity in a safe environment without compromising patient safety.[5,6,7] It is used to ensure students have a degree of clinical competence before exposure to real patients, enhancing the application of theoretical knowledge to clinical practice.[7] Immersive simulation can be a useful tool to engage learners and provide experiences to train learners in scenarios that may occur infrequently.[6] Simulation-based medical education has been utilized to enhance teaching effectiveness through reflective learning, deepening learner understanding and awareness of human factors in healthcare delivery.[6,8,9] Recently, immersive simulation has been adopted in veterinary educational settings. This teaching tool particularly allows veterinary students to experience simulated incidents involving animals and people where they can practice working as part of a multidisciplinary team in high-pressure, high-stakes scenarios. This has broadly mirrored, but lagged behind, the training provided to undergraduate and postgraduate medical students.[10,11,12]

It is critical that immersive simulation scenarios are realistic, undertaken in a safe, supportive environment, and that individuals trained in debriefing methods form part of the teaching team.

To date, immersive simulation in veterinary education has often been ad hoc without a specific focus on the emotional and cognitive effect on the participants.[11,12] Immersive simulations should focus on a small number of specifically defined learning outcomes and are not designed to drill participants in clinical procedures but instead to develop analytical reasoning and an appreciation of how human factors may affect performance.[13]

Cognitive load theory states that working memory is finite.[14] Many researchers have found that learning is impaired when an experience overloads the brain's capacity to process and transfer knowledge to long-term memory[1]. In order to function effectively in multiple veterinary high-stakes situations, veterinarians must recognize the signs of pressure overload and the signs of the low performance state of frazzle. Frazzle is defined as a state of extreme physical or nervous fatigue and agitation. [15] In undergraduate veterinary training, we can embed a toolkit for dealing with pressure and overload. Participation in high-pressure immersive simulation scenarios significantly influences the participants' emotional state and potentially overwhelms their cognitive load. Careful scenario design facilitates learners in the application and practice of their training and may allow them to refine and embed their skills and essential knowledge. A structured debrief of participants may help to ensure that learners do not experience undue emotional stress or excessive extraneous load on their working memory.[14]

As an educator, it is imperative to set the cognitive load of an experience to maximize the learning potential. Although previous studies in medical education have evaluated the effect of immersive simulation on participants' emotional state and cognitive load[1] studies addressing simulation of high-stakes veterinary scenarios are lacking.

This study aimed to assess the cognitive load, and emotional states of students undertaking an immersive simulation developed to simulate a degree of situational chaos.

Materials and Methods

Ethical approval

The Human Ethics Review Committee granted ethical approval for this study at the Royal (Dick) School of Veterinary Studies, University of Edinburgh, Ref HERC 709-21.

Curriculum context

Increasingly, veterinary curricula focus on developing the attitudes and aptitudes necessary for successful performance in veterinary practice. The development of core competencies necessary for this has recently revolved around a set of “first day skills” or core competencies[4] which should be embedded by graduation. However, it is recognized that a group of "non-technical skills” and human factors, including the attributes of resilience, flexibility, and adaptability, are crucial in developing high-performing veterinarians. The development of the immersive simulation training described in this paper is an attempt to develop structured training for these attributes in a psychologically safe space.

Study design

The inclusion of a course on Peak Performance under Pressure[16] and the role of human factors in veterinary performance was approved by the School Learning and Teaching Committee. Ethical approval was sought and obtained from the ethics committee for a study to attempt to evaluate the effects of this teaching on the emotional and cognitive loads of student participants.

All student participants had attended training in large animal rescue techniques and had completed all clinical theory training prior to beginning final year rotations. A lecture on the effect of pressure and high-stakes situations on performance, including a toolkit of techniques for managing pressure, was given to all participants prior to the practicals. A practical class structured around a scenario based upon a real-life road traffic collision was set up as detailed below. The peak performance under pressure course included a series of lectures and practicals across all years of the veterinary course. The course focused on training in metacognition, the arc of performance, the relationship between competence and confidence, the effect of pressure on individual and team decision-making, communication under pressure, cognitive biases, and provided training in a set of specific pressure relief techniques (“toolkit for owning the pressure”), drilling and simulation for high stakes situations. The course was modelled on similar training programs in human medicine, mountain rescue, first responders, and the aviation industry [16].

Simulation scenario

This prospective observational study was undertaken during immersive simulation training for attending incidents involving animals. Written informed consent was obtained from all participants. All participants took part in a standard pre-scenario briefing, including a psychological safety briefing, prior to the beginning of the first scenario. Psychological safety of learners was a priority. This was established during the scenario prebriefing by introduction of the facilitators and the scenario and describing the learning contract. During the debrief, psychological safety was supported using the implicit strategies (eye contact, listening, empathy) and explicit strategies (including validation and paraphrasing and authenticity). After taking part in the first scenario and before the debrief, students were asked to score their emotional and cognitive loads.

Setting and scenario, participants, and equipment

Full details of the scenarios, including details of equipment, a picture of the set-up, scripting and timing of events is included as a supplementary file to this article (see Figure, Supplementary Digital Content 1, equipment set up) (see document, Supplementary Digital Content 2, details of the scenario). Each training session was undertaken in the simulation teaching area of the Equine Hospital, and the same scenario was used for each training session. The scenario was based on a road traffic collision attended by one of the authors. It consisted of a simulated multi-casualty (human and animal) road traffic collision involving a wrecked car, 250 kg life-sized equine manikin[a] (Resquip Ltd), a canine manikin[b] (Rescue Critters canine manikin), and a live simulated human passenger casualty. The following actors were involved; the injured car driver trapped in the car by the forelimbs of the horse that had penetrated the windscreen, the horse owner, a first responder, and a passer-by. The scenario briefing was that the paramedics could not access the human casualty until the horse was made safe and removed; in addition, the driver would not accept medical treatment until the status of the canine casualty had been ascertained. Multiple distracting influences were in line with events in the real-life scenario upon which the simulation was based. These included the owner of the injured horse, who was very vocal and in a state of crisis, the presence of another equid casualty (played by a live horse from the teaching herd) around the scene, a well-meaning member of the public who was directing others to place themselves at risk, the first responder, and audio recordings of a distressed horse and a distressed dog. The successful scenario resolution required the students to demonstrate situational awareness, task prioritization and to work as part of a multidisciplinary team with other first responders.

Each session involved participants experiencing the scenario on two occasions, initially before a structured debrief including revision of previous training in pressure relief techniques, followed by a re-run of the scenario. Two experienced facilitators ran the session. Body cameras were used to obtain material to review during the debrief. The use of body cameras in simulation training was covered by a university data protection impact assessment (DPIA) to comply with general data protection regulations (GDPR). Recordings were used for the training session and deleted immediately after that.

A COVID-19 risk assessment was in place for training in the Equine Simulation area, and all COVID-19 mitigation measures were followed.

Each simulation group comprised 10 participants; all were penultimate-year veterinary students.

The scenario was run from the point of arrival of the veterinary first responders to the point when the horse was "made safe." Participants played the part of vets, vet nurses, or observers. Participants changed roles between scenarios one and two.

Debrief and Assessment

After the first and repeat scenario run before the debrief, students were asked to score their emotional and cognitive loads. Emotional load was scored using a tool described by Feldman

Barret and Russell and supported by evidence of validity in broadly similar applications .[17,18,19] This tool had eight items describing an opposite affect or emotional state. The eight items were tense/calm, nervous/ relaxed, stressed/serene, upset/content, sad/happy, depressed/elated, lethargic/excited, and bored/alert. Participants were asked to rate their emotions for each item on a five-point Likert scale (−2 to +2). A positive value was assigned to the positive emotional state and a negative value to the opposite negative emotional state, as previously reported by Fraser *et al.*[18]

The cognitive load of the participants during the simulation was assessed on a nine-point symmetrical category scale ranging from very, very low mental effort (1) to very, very high mental effort (9), as described by Paas and Van Merriënboer.[14] The participants were asked to rate their emotional state and cognitive load after completing the first simulation scenario and again after the debrief and a re-run of the scenario.

The evaluation tools were created to measure the relative load on the working memory of an educational experience. [18,20] This tool ranged from 1 (very, very small effort) to 9 (very, very high effort). This and other studies suggest that performance declines at a load of 7 or more.

The debriefing session was structured using a hybrid of the Pearls and the plus-delta self-assessment-led debriefing approaches with particular consideration for the psychological safety of participants. Debriefing is a structured discussion of performance to identify knowledge and skill development opportunities. [21,22,23] Debriefing began with a collection of participants' emotional reactions, followed by their description of the simulated incident and a self-evaluation of how they performed during the scenario. A focused facilitated discussion around the key performance points of the scenario followed this. Feedback was predominantly via guided team self-correction with some directive feedback when required to correct perception mismatches and summarise key learning points.

Follow-up meeting and questionnaire.

One week after the simulation class, an online discussion was held as a cold debrief of the learning experience. During this discussion, participants completed an anonymous questionnaire with free text questions, including on their performance state during each scenario run and which, if any, of the taught pressure relief techniques ("toolkit for owning the pressure") they had used. There was also a free text section; the results of this are in Table 3.

Statistical Analysis

It was considered that cognitive and emotional state could vary by scenario (e.g., scenario run 1 versus scenario run 2) and status within the scenario (e.g., participant then observer, observer then participant, participant then participant, observer then observer). To account for both potential effects, a linear mixed-effects model was run for each response (cognitive load and emotional state) with scenario order and status as fixed effects, along with an interaction between run order and status. Student ID was fitted as a random intercept. The package used was lme4. [24] The ggstatsplot package [25] was used to visualize coefficient and effect direction estimates. All data were analyzed in R (Version 4.0.2, "Taking Off Again," R Core Team 2020) and with the use of the tidyverse packages for data processing. [26,]

Sampling was opportunistic, e.g. all students available to participate were invited to participate. This was an exploratory first-steps study with no existing information on this scale being utilised with this population. As a result, there was no prior information regarding the expected effect size. Consequently, it was not appropriate to calculate a sample size prior to the analyses. [27]

Results

One hundred twenty-five veterinary students participated in the simulation, and all consented to enroll.

Cognitive Load

Across both run scenarios, cognitive load was generally moderate ($\bar{\mu}$Scenario run 1 = 4.44 ± 1.85 (SD), $\bar{\mu}$Scenario2 = 5.69 ± 1.74 (SD), Figure 1), and observers and participants had similar ratings (Observers $\bar{\mu}$ =5 ± 1.83(SD), Participants $\bar{\mu}$ =5.07 ± 1.93(SD). Students who were participants in scenario run 2 had a significantly higher rating on cognitive load versus those who were observers during scenario run 2 (Diff = 1.43, 95% CI [0.33, 2.52]), but scenario run order and status had no impact on the students ratings of their cognitive load (Figure 2).

Emotional State

The distribution of emotional states across run scenarios and participation status is given in Figure 2. The central tendency of emotional states ranged between -0.9 to 1.3, suggesting strong emotional states were not common throughout the experience.

Bored-Alert Spectrum

There was no impact of either scenario run order or status on the participants self-rating on the Bored-Alert spectrum (Table 1, Figure 2)

Depressed-Elated Spectrum

In scenario run 2, students rated themselves closer to the ‘elated’ side of the depressed-elated spectrum by 0.47 points (95% CI [0.21, 0.74], $t(244) = 3.45$, $p < .001$). There was no interaction between run order and participation status and no impact of participation status on their ratings on the depressed-elated spectrum (Table 1, Figure 2).

Lethargic-Excited Spectrum

There was no impact of either scenario run order or status on the participants self-rating on the Lethargic-Excited spectrum (Table 1, Figure 2).

Nervous-Relaxed Spectrum

In scenario run 2, students increased their rating on the nervous-relaxed spectrum by 0.95 (95% CI [0.49, 1.41], $t(245) = 4.05$, $p <.001$), i.e., they were more relaxed. There was no impact of participation status or the interaction between participation status and run order on students' self-ratings on the nervous-relaxed spectrum (Table 1, Figure 2).

Sad-Happy Spectrum

Students rated themselves as 0.44 (95% CI [0.09, 0.79], $t(247) = 2.45$, $p = .015$) points more 'happy' on the sad-happy spectrum in scenario run 2 compared to scenario run 1. There was no impact of participant status or interaction between status and run order on students' ratings on the sad-happy spectrum (Table 1, Figure 2).

Stressed-Serene Spectrum

In scenario run 2, students rated themselves as 1.03 points more serene (95% CI [0.56, 1.50], $t(245) = 4.32$, $p < .001$) on the stressed-serene spectrum (Table 1, Figure 2).

Tense-Calm Spectrum

In scenario run 2, students rated themselves 1.19 points calmer on the tense-calm spectrum compared to scenario run 1 (95% CI [0.68, 1.70], $t(245) = 4.57$, $p<.001$). There was no impact of status or interaction between status and run order on students' self-ratings on the tense-calm spectrum (Table 1, Figure 2).

Upset-Content Spectrum

Students rated themselves 0.84 points more content on the upset-content spectrum (95% CI [0.44, 1.24], $t(247) = 4.16$, $p < .001$) in scenario run 2 compared to scenario run 1. There was no impact of participation status or the interaction between status and run order on the students' ratings on the upset-content spectrum (Table 1, Figure 2).

Results of the round-up questionnaire

The majority of participants described that they were in a state of frazzle during scenario 1 compared to a majority that described being in a state of flow during scenario 2 following the structured debrief (Table 2.). Seventy-seven percent of participants stated that the second scenario was easier than the first, and 2% stated that it was more challenging due to expectations to improve. Participants described what they enjoyed most and least, what emotional changes they had experienced, and what, if any, pressure relief techniques they had used. They also made suggestions for how the class could be improved. These data are presented in Table 3. Additional analysis of this qualitative data is the focus of a further ongoing study.

Discussion

High-stakes veterinary immersive simulation scenarios are complex and, alongside clinical skills, involve non-technical skills such as teamwork, communication, and an appreciation of the effect of human factors on performance. The evidence suggests that immersive simulation scenarios should have a tightly defined, small number of specific learning outcomes, in this case, focused on developing skills for peak performance in a high-stakes veterinary scenario.[13,1]

This study reports that measuring participants' cognitive load and emotional experience in a well-designed immersive simulation high-stakes veterinary scenario may be possible. The participants in this study demonstrated relatively higher cognitive load with more positive emotional states during the second scenario run, following the completion of a structured debrief and discussion focusing on pressure relief techniques. Following a debrief and first experience of the scenario, the second attempt was a more positive experience despite no change in scenario complexity. The same scenario was repeated based on evidence from the medical educational literature that such a construct results in improved knowledge, problem solving, confidence, critical thinking and clinical competence. [28,29,30,31] It is generally accepted that a cognitive load between 3 and 6 out of 9 is associated with a maximal learning experience and a score of above 7 results in declined performance. [31,1,32] In our study, cognitive load was within the range described to maximise the learning experience. Participants scored themselves as more elated, more relaxed, calmer, more serene, and more content in scenario 2 compared to scenario 1. Veterinary educators who take the time to design and construct an immersive simulation scenario with cognitive load in mind may be more successful in refining the amount of strain imposed on learner working memory.[33] The inclusion of a structured debrief also has the potential to affect cognitive load and results in a more positive emotional state.[34] Evidence from the literature suggests that the debriefing session is the most important part of the simulation activity, and that post-stimulation debrief allows participants to experience the consequences of their errors producing a high level of realism. In the study described here, the purpose of the repeat simulation was to allow participants an opportunity to apply this learning to the simulated situation. [35,36] In addition, during this simulation, the majority of participants described moving from the low-performance state of frazzle to the high performance state of flow, from scenario run 1 to scenario run 2, with many of the participants also describing the use of a variety of the techniques which had been described in the lecture which preceded the simulation for coping with high-pressure situations.[16]

Individuals in high-stakes situations are subjected to various stimuli, stressors, and pressures. The effect of these environmental, organizational, job, and human and individual characteristics influencing our behavioral responses are referred to as human factors.[37] While other industries, particularly aviation, have invested much time and effort to determine these human factors' effect on their teams' performance, this concept is relatively new in veterinary medicine.[9,12]

It is accepted that some pressure promotes performance and that specific amounts of pressure result in high performance. In the presence of the correct pressure level, tasks are completed efficiently, and the perception of challenge leads to peak mental arousal with improved dexterity, reaction times, and cognitive ability. Conversely, excessive cognitive load, emotional reactions, and stress-induced activation of our sympathetic nervous system are detrimental to our ability to perform in high-stakes situations.[38] In 1908, Yerks and Dodson[39] suggested that moderate stimulus is generally best; when stimulus is very high or very low, performance tends to suffer. The work was derived from a set of experiments in Japanese dancing mice learning to discriminate between white and black boxes using electric shocks. This research was largely ignored until the 1950s when Hebb's concept of arousal and the "U-shaped curve" led to the so called "Yerkes-Dodson law".[40,41] This inverted U theory of pressure and performance, or "arc" of performance recognizes three states of performance ability in relation to the level of pressure experienced by individuals or teams: disengagement, flow, and frazzle. With increasing cognitive load, motivation, and pressure levels, performance improves, and teams and individuals become more aroused and task-focused. This results in an improvement in our mental processing, physical abilities, decision-making, creative, and psychomotor abilities, which all increase to the most appropriate level for the task. We achieve a state of arousal and performance appropriate to our task or tasks, referred to by psychologists as the state of flow.[42,38,43] When in flow, our bodies secrete low concentrations of stress hormones, which help to maintain a state of arousal and focussed attention in which, although we may perceive the situation as challenging, we nevertheless have the confidence, skills, knowledge, and resources to achieve a resolution of the situation safely and favorably.[38] The state of flow was first described by psychologist Mihály Csíkszentmihályi in 1990 as[42]: "being completely involved in an activity for its own sake. The ego falls away, time flies, and every action, movement, and thought follows inevitably from the previous one, like playing jazz. Your whole being is involved, and you're using your skills to the utmost." The psychologist Goleman described flow as "a state of maximum cognitive efficiency. Getting into flow lets you use whatever talent you may have at peak levels.". In a high-stakes veterinary situation, flow is when we are professionally at our best and can undertake physical tasks efficiently, safely, and quickly. Our communication becomes highly effective, and our abilities to innovate and plan are at their highest.

Conversely, we can also develop negative emotional responses when the pressure becomes excessive. In the flow state, we perceive the situation we face as challenging. With focussed effort, we see the challenge as surmountable. With increasing pressure, however, our emotional brain starts to change its perception from one of challenge to one of threat. This leads to the release of cortisol and adrenaline from the adrenal glands and the development of a stress response. In this state of excessive pressure, we experience cognitive overload; we find it difficult to make accurate judgments, communicate effectively, or complete practical procedures efficiently. This state of excessive pressure and poor performance is referred to as frazzle. [15,16] When we reach this zone of frazzle, our insight into our psychological state is impaired. Frazzled individuals and teams find it difficult to appraise their circumstances and rapidly lose perspective. Without practicing suitable coping strategies in advance, it is likely impossible to regain composure and situational awareness. Individuals in a state of frazzle often develop a negative feedback cycle, i.e., the more overwhelmed they feel, the greater the physical stress response, leading to a downward spiral of ability to perform or to regain control.

In cases of extreme frazzle, we can completely lose the ability to make decisions, communicate or take in our surroundings, this is known as choking or freezing.[44]

In a high-stakes, high-pressure situation, the human prefrontal cortex is programmed to come up with an appraisal of the situation in milliseconds; it compares the situation to previous experience and comes up with one of two possible options, either; while there may be multiple challenges and pressures, the brain determines that you the have the ability and resources to complete it with a good outcome, or that the opposite is true and the brain comes up with an appraisal of threat. These responses are inherent and cannot be stopped. If the brain arrives at option two, the result is the release of cortisol and adrenaline and the rapid transition to the low-performance situation and frazzle. However, with experience, it is possible to recognize the development of these emotional and cognitive states, learn not to react to frazzle, and come up with a learned measured and objective response. In the study described here, the use of a structured debrief, a toolkit for “owning the pressure," and the ability to practice the scenario on two occasions, and therefore inherent familiarity with the event, led to a tendency for the participants to move from a state of frazzle in the first scenario run to a state of flow in scenario run two.

Strengths and limitations

This is the first description of the use of immersive simulation for training in high-stakes situations in veterinary medicine and the first attempt to evaluate emotional states, cognitive load, and pressure on participants in a veterinary immersive simulation. The most challenging component of the design of this study and one of the biggest limitations, both with the scoring and qualitative feedback is that there was no comparison group. Consequently, it is difficult to determine if the findings are related to debriefing, or participating in a simulated event, or perhaps a combination of both. It is also possible that due to the fact the same scenario was used twice, that during the second scenario run, increased familiarity with the same event alongside clinical, communication, and team challenges had an impact on the scores for emotional and cognitive load.[36]

In common with findings in human medical simulation,[1,45] this study suggests that it may be possible to measure emotional and cognitive load using the tools developed by Paas and Van Merriënboer[14] and employed by others for the same purpose. [46,47,19] While other tools are available,[48] and although the tools used in this study appeared to have been used in high stakes medical or critical care settings previously, they are different to the realistic event included in this study and so could be considered a further limitation.

It would be interesting to associate cognitive load score with development of skills in the future.[49,50,51,52] This could be challenging as it would involve linking the simulation experience to measured improvements in performance for each participant. Future studies may focus on tailored simulation scenarios for team training, emphasizing particular outcomes.[45,53,54] These studies could look for relative improvements in the outcome as a demonstration of effective development of skills and training.

Conclusion

Measurement of cognitive load and emotional impact of immersive simulation in education in a high-stakes veterinary environment is feasible. Moreover, a well-designed, high-fidelity simulation scenario has the potential to positively affect participants' emotional state when combined with an appropriate debrief and training in performance techniques. The movement of learners emotionally from a more negative state to a positive state suggests that simulation is a tool that could be used for improved skills training, to offer more opportunities for dynamic thinking, and to potentially allow participants to develop strategies for coping with pressure in future situations.

Further studies are needed to assess the different components of cognitive load, nevertheless, it is hoped that immersive simulation with structured debrief will become commonplace in veterinary education.

Acknowledgments

The authors gratefully acknowledge the help of the students who took part in this immersive simulation class, Dr. Karen Gardiner, the Scottish Fire and Rescue Service, and the staff of the Royal (Dick) School of veterinary studies who supported the project.

Financial Disclosure Summary

The authors declare no financial interests in the work presented which was carried out as part of their standard employment. No specific funding was obtained for the study.

References

1. Pawar S, Jacques T, Deshpande K, Pusapati R, Meguerdichian MJ: Evaluation of cognitive load and emotional states during multidisciplinary critical care simulation sessions. BMJ Sumul. Technol. Enhanc. Learn 2018; 4(2): 87-91.

2. Holden CL: Characteristics of veterinary students: perfectionism, personality factors, and resilience. Journal of Veterinary Medical Education 2020; 47(4), 488-496.

3. Dalla Villa P, Watson C, Prasarnphanich O, Huertas G, Dacre I: Integrating animal welfare into disaster management using an 'all-hazards' approach. Rev Sci Tech 2002;39(2):599-613.

4. Royal College of Veterinary Surgeons (RCVS) first day competencies framework. https://www.rcvs.org.uk/news-and-views/publications/rcvs-day-one-competences-feb-2022/?destination=%2Fnews-and-views%2Fpublications%2F

5. Weller JM: Simulation in undergraduate medical education: bridging the gap between theory and practice. Medical education 2004; *38*(1):32-38.

6. Aggarwal R, Mytton OT, Derbrew M, Hananel D, Heydenburg M, Issenberg B, MacAulay C, Mancini ME, Morimoto T, Soper N, Ziv A, Reznick R: Training and simulation for patient safety. Qual Saf Health Care 2010;19 Suppl 2:34-43.

7. Weller JM, Nestel D, Marshall SD, Brooks PM, Conn JJ: Simulation in clinical teaching and learning. Medical Journal of Australia 2012; *196*(9):594-594.

8. Small SD: Simulation applications for human factors and systems evaluation. Anesthesiology Clinics 2007;*25*(2):237-259.

9. Saleh GM, Wawrzynski JR, Saha K, Smith P, Flanagan D, Hingorani M, John C, Sullivan P: Feasibility of human factors immersive simulation training in ophthalmology: The London pilot. JAMA ophthalmology 2016;*134*(8):905-911.

10. Okuda, Y, Bryson, EO, DeMaria, S, Jr, Jacobson, L, Quinones, J, Shen, B, Levine, AI: The utility of simulation in medical education: what is the evidence? Mt. Sinai. J. Med.2009; Aug;76(4):330-43.

11. Fletcher DJ, Militello R, Schoeffler GL, Rogers CL: Development and evaluation of a high-fidelity canine patient simulator for veterinary clinical training. J. Vet.Med. Educ 2012; 39(1):7-12.

12. Jones JL, Rinehart J, Englar RE: The Effect of Simulation Training in Anaesthesia on Student Operational Performance and Patient Safety. J Vet Med Educ 2019;46(2):205-213.

13. Khan K, Pattison T, Sherwood M: Simulation in medical education. Med Teach 2011;33(1): 1-3.

14. Paas FGWC, Van Merriënboer JJG: The Efficiency of Instructional Conditions: An Approach to Combine Mental Effort and Performance Measures. Human Factors 1993;35(4):737-743.

15. Arnsten AF: The biology of being frazzled. Science (New York, N.Y.); 1998 280(5370), 1711–1712.

16. Hearns S: Peak Performance Under Pressure: Lessons from a Helicopter Rescue Doctor. http://www.corecognition.co.uk Accessed May 2021.

17. Barrett LF, Russell JA: Independence and Bipolarity in the Structure of Current Affect. J. of Personality & Social Psychology 1998;74(4):967-984.

18. Fraser K, Ma I, Teteris E, Baxter H, Wright B, McLaughlin K: Emotion, cognitive load and learning outcomes during simulation training. Med. Educ 2012; 46:1055–1062.

19. Fraser K, Huffman J, Ma I, Sobczak M, McIlwrick J, Wright B, McLaughlin K: The emotional and cognitive impact of unexpected simulated patient death: a randomized controlled trial. Chest 2014 May;145(5):958-963.

20. Fraser KL, Ayres P, & Sweller J: Cognitive load theory for the design of medical simulations. Simulation in Healthcare 2015; 10(5), 295-307.

21. Eppich W, Cheng A: Promoting Excellence and Reflective Learning in Simulation (PEARLS), Simulation in Healthcare: The Journal of the Society for Simulation in Healthcare 2015; (10):106-115.

22. Cheng A, Eppich W, Epps C, Kolbe M, Meguerdichian M, Grant V: Embracing informed learner self-assessment during debriefing: the art of plus-delta. Adv Simul (Lond) 2021;5,6(1):22.

23. Kolbe M, Eppich W, Rudolph J, Meguerdichian M, Catena H, Cripps A, Grant V, Cheng A: Managing psychological safety in debriefings: a dynamic balancing act. BMJ simulation & technology enhanced learning 2020; 6(3):164-171.

24. Bates D, Mächler M, Bolker B, Walker S: Fitting Linear Mixed-Effects Models Using lme4. J. Statistical Software 2015; 67 (1):1-48.

25. Patil I, Powell C: ggstatsplot:"ggplot2" based plots with statistical details 2018;CRAN.

26. Wickham H, Averick M, Bryan J, Chang W, McGowan LD, François R, Grolemund G, Hayes A, Henry L, Hester J, Kuhn M: Welcome to the Tidyverse. Journal of open source software 2019;21;4(43):1686.

27. Noordzij M, Tripepi G, Dekker FW, Zoccali C, Tanck MW, Jager KJ. Sample size calculations: basic principles and common pitfalls. Nephrol Dial Transplant. 2010;25(5):1388-93.

28. Morgan PJ, Morgan PJ, Cleave-Hogg D, Morgan PJ, Cleave-Hogg D, Desousa S, Morgan PJ, Cleave-Hogg D, Desousa S, Lam-Mcculloch J, Morgan PJ: Applying theory to practice in undergraduate education using high fidelity simulation. Medical teacher 2006 Jan 1;28(1):e10-5.

29. Carter H, Hanks S, Gale T: A qualitative study using hybrid simulation to explore the impacts of human factors e-learning on behaviour change. Advances in Simulation 2020 Dec;5(1):1-0.

30. Zulkosky K, Minchhoff D, Dommel L, Price A, Handzlik BM: Effect of repeating simulation scenarios on student knowledge, performance, satisfaction and self-confidence. Clinical Simulation in Nursing 2021 Jun 1;55:27-36.

31. Rogers B A, Franklin AE:Cognitive load experienced by nurses in simulation-based learning experiences: An integrative review. Nurse education today 2021; 99, 104815.

32. Fraser KL, Meguerdichian MJ, Haws JT, Grant VJ, Bajaj K, Cheng A: Cognitive load theory for debriefing simulations: implications for faculty development. Advances in Simulation 2018; Dec;3(1):1-8.

33. Alessi SM: Fidelity in the design of instructional simulations. J. Comput. Case Instr 1998;15:40–47.

34. Farrington R, Collins L, Fisher Danquah A, Sergent J: Clinical Debrief: learning and well-being together. Clin Teach 2019;16(4):329-334.

35. Van Heukelom, Jon N. MD; Begaz, Tomer MD; Treat, Robert PhD. Comparison of Postsimulation Debriefing Versus In-Simulation Debriefing in Medical Simulation. Simulation in Healthcare: The Journal of the Society for Simulation in Healthcare 2010; 5(2):p 91-97.

36. Al Gharibi, MSN KA, Arulappan, MSc (N), PhD, DNSc J: Repeated simulation experience on self-confidence, critical thinking, and competence of nurses and nursing students—An integrative review. SAGE open nursing 2020 May;6:2377960820927377.

37. Jones CPL, Fawker-Corbett J, Groom P, Morton B, Lister SJ: Human Factors in preventing complications in anesthesia: a systematic review. Anaesthesia. Suppl 2018;1: 12-24.

38. Nideffer R.M: Getting into the optimal performance state https://www.epstais.com/articles/optimal.pdf Accessed May 2021

39. Yerkes RM, Dodson JD: The relation of strength of stimulus to rapidity of habit-formation. J. of comp. neuro. and psychol1908;18:459-482.

40. Hebb DO. Drives and the CNS (conceptual nervous system). Psychological review. 1955 Jul;62(4):243

41. Teigen KH. Yerkes-Dodson: A law for all seasons. Theory & Psychology. 1994 Nov;4(4):525-47

42. Csikszentmihalyi M: Flow: The Psychology of Optimal Experience." Journal of Leisure Research1990;24(1):93–94.

43. Goleman D: The brain and emotional intelligence: New insights. Published by More than sound LLC.

44. Roelefs K: Freeze for action: neurological mechanisms in animal and human freezing. Phil. Trans. R. Soc 2017; 372.

45. Fraser K, Huffman J, Ma I, Sobczak M, McIlwrick J, Wright B, McLaughlin K: The emotional and cognitive impact of unexpected simulated patient death: a randomized controlled trial. Chest 2014; 145:958–963.

46. Klepsch M, Schmitz F, Seufert T. Development and Validation of Two Instruments Measuring Intrinsic, Extraneous, and Germane Cognitive Load. Front Psychol. 2017; 16;8:1997.

47. Ouwehand K, Kroef AV, Wong J, Paas F. Measuring cognitive load: Are there more valid alternatives to Likert rating scales?. In: Frontiers in Education 2021; Sep 20 (Vol. 6, p. 702616). Frontiers Media SA.

48. Hart SG, Staveland LE. Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In: Advances in psychology 1988; Jan 1 (Vol. 52, pp. 139-183). North-Holland.

49. LeBlanc V, Woodrow SI, Sidhu R, Dubrowski A: Examination stress leads to improvements on fundamental technical skills for surgery. Am J Surg 2007;196(1).

50. Saunders T, Driskell JE, Johnston JH, Salas E: The effect of stress inoculation training on anxiety and performance. J. Occup. Health Psychol 1996;1(2):170-86.

51. Salas E, Maurino D, Curtis M: Human factors in aviation: an overview. Human factors in aviation 2010;1:3-19.

52. Sandi C: Stress and cognition. Cogn. Sci 2013;4:245-261.

53. Salas, E and Maurino D: Human Factors in Aviation, 2nd edition. Elsevier

54. Fraser KL., Ayres P., Sweller J: Cognitive load theory for the design of medical simulations. Simul. Health 2015;10:295–307.

Equipment a -Equine Rescue manikin http://www.resquip.com/

b -Canine manikin https://rescuecritters.com/

Figure Legends and Supplementary Digital Content Files

Figure 1: Figure 1: 'Raincloud' plot displaying sample density (the 'cloud' on top), individual data points (the middle 'rain drops') and summary statistics (the boxplot 'land') for cognitive load scores between observers and participants (left) and Run1 and Run 2 (right)

Figure 2: 'Raincloud' plot displaying sample density (the 'cloud' on top), individual data points (the middle 'rain drops') and summary statistics (the boxplot 'land') for emotional state scores between observers and participants (right) and Run1 and Run 2 (left)

Supplementary Digital Content 1. Picture showing the simulation in progress illustrating the set up with manikin, actors, and participants.

Table 1: Table of coefficients for linear mixed model for each emotional variable

Table 2: Changes in performance state from scenario one to scenario two

Table 3: Results of anonymous free text questionnaire

Supplementary Digital Content 2. Full details of the scenario including script.