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Registered nurses psychophysiological stress and confidence during high-fidelity emergency simulation: Effects on performance

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ABSTRACT

Introduction: Simulation has been used extensively to train students and health professionals in the assessment and early intervention of patients with acutely deteriorating conditions. These simulations evoke psychophysiological stress in learners which may affect performance. We examined the relationship between stress variables, confidence, and performance during repeated scenarios in clinically-based emergency simulations.

Methods: Twenty-six registered nurses completed three simulation scenarios focussing on life-threatening clinical events in a single group pre-test/post-test study design. Trait anxiety was measured at baseline. Visual analogue ratings of anxiety and stress were measured before ('*pre*'), recalled '*during*', and immediately following ('*post*') each simulation scenario, with a self-rating of confidence completed after each simulation scenario. Heart rate was measured continuously throughout the simulation program. Participants self-rated their clinical performance prior to and following the simulation program ('*pre*' and '*post*').

Results: Participants' trait anxiety was not elevated at baseline (mean: 39.6, SD 6.1). Across the three simulation scenarios, anxiety and stress was elevated '*during*' simulation compared to '*pre*' and '*post*' time points. However, the magnitude of elevation of stress and anxiety during all time points ('*pre*', '*during*' and '*post*' simulation) decreased significantly ($p < 0.05$) with progressive simulations. Heart rate increased significantly during all simulations compared to '*pre*'-levels but returned to similar levels following the simulation. The amount of increase in heart rate over progressive simulations was attenuated during simulation 3 compared with 1 and 2 (Sim 1: 103.6 bpm (SD 22.1), Sim 2: 101.9 bpm (SD 18.9), and Sim 3: 99.5 bpm (SD 23.4)). Confidence increased across the three simulations ($p < 0.001$), with most of the increase observed after the first two simulations. Performance scores increased by 19.0% '*pre-post*' simulation program ($p < 0.001$) and were not confounded by previous ALS or simulation experience.

Discussion: We observed temporal-dependent changes in psychophysiological stress variables across the simulation scenarios, with decreased magnitudes of elevations of psychological (self-reported anxiety and stress) and physiological (heart rate) stress variables during successive simulation scenarios. This study has shown that simulation increased stress, especially before and during scenarios; however, the learning effect decreased the magnitude of the stress response with repeated simulation scenarios. Simulation educators need to create simulations that change stress in a purposeful manner to enhance learning.

1. Introduction

Delayed assessment and management of the deteriorating patient can result in poor patient outcomes and avoidable intensive care admissions (Stayt et al., 2015). A consensus statement by the Australian Commission on Safety and Quality in Healthcare (Australian Commission on Safety and Quality in Health Care, 2010) has emphasised the need for the acute care workforce to be appropriately trained in identifying and managing patient clinical deterioration. Nurses play a vital role in the recognition and management of patient deterioration due to their predominant exposure with patients, especially in clinical settings. Stress may affect nurses' clinical performance and therefore it is essential that nurses are exposed to similar stressful, clinically-meaningful, experiences during their education. There has been a widespread uptake of simulation-based education for early identification and management of the deteriorating patient (Gordon and Buckley, 2009); however the effect of stress on confidence and performance during these simulations in nurses has received little attention. Previous

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research has shown that registered nurses perform poorly in their ability to manage the deteriorating patient during simulation training (Bogossian et al., 2014; Cooper et al., 2011).

High-fidelity simulation can be used to replicate clinical emergencies in hospital-based settings. This permits realistic training in a safe environment to improve learning (Drews and Bakdash, 2013; Jones et al., 2011). Evidence suggests that simulation-based education for the training of managing the deteriorating patient produces favourable educational outcomes. Simulation was superior in developing advanced life support skills compared to clinical experience alone in medical residents (Wayne et al., 2005) and for improving patient outcomes (Moretti et al., 2007). Registered nurses had improved knowledge and confidence following high-fidelity simulation scenarios (Bliss and Aitken, 2018; Disher et al., 2014). Similarly, nursing students, in randomised controlled trials, whom underwent simulation training, showed superior recognition and assessment of deteriorating patients compared to control groups (Liaw et al., 2011; Merriman et al., 2014; Stayt et al., 2015).

Stress is categorised by physical, mental, and/or emotional strain or tension experienced when a person perceives that expectations and demands exceed available personal or social resources (Levine et al., 2013). Educators can optimise the learning environment and learners can maximise the effectiveness of simulation-based educational experiences when the stress levels of participants are considered and responsive to learning (Judd et al., 2016; Levine et al., 2013). There is strong evidence that clinical simulation generates elevated stress in health professionals and students (Bong et al., 2010; Cantrell et al., 2017; Girzadas et al., 2009; Jones et al., 2011; Judd et al., 2016; Kharasch et al., 2011; Müller et al., 2009; Pottier et al., 2013; Wetzel et al., 2010) and whilst it has been suggested to affect learners performance, there is a paucity of data that examines the effect of simulation stress on performance. In one study, nursing student anxiety did not appear to negatively impact their ability to perform in simulation (Shepherd et al., 2010); yet, in another study, elevated stress was observed to impair the clinical reasoning of medical students (Pottier et al., 2013). Similarly, conflicting evidence has been reported from a review about the influence of anxiety on the performance of undergraduate health professionals, (predominantly from nursing and medicine) that simulation can either enhance or deteriorate performance (Al-Ghareeb et al., 2017). The dose response of stress and performance is likely to be important, with Yerkes Dodson Law proposing optimal performance at a moderate level of anxiety and reduced performance associated with high levels of anxiety (Yerkes and Dodson, 1908).

Simulation training, facilitated by experiential learning, is commonly tailored to include multiple scenarios in a single day. The effect of repeated scenarios on stress, confidence and performance is unclear. A recent study suggests that anxiety may decrease with repeated sessions with performance scores increasing (Rossignol, 2017). As simulation is an established educational tool for the teaching of advanced life support skills, the impact of psycho-physiological stress responses during simulation needs to be understood to maximise learning opportunities. Therefore, the aim of this study was to examine the psychophysiological stress in registered nurses during a series of simulated clinical emergency scenarios with respect to their confidence and performance. It was hypothesized that the simulation scenarios would elicit an elevated stress response (compared to baseline) and that with exposure to successive scenarios confidence would increase along with an increase in '*pre-post*' performance.

2. Methods

This prospective cohort study utilises a single group pre-test/post-test design. The study was conducted with registered nurses undertaking post-graduate studies at a large Australian metropolitan university. Participants were enrolled in a unit of study that focussed on the early identification and management of patients with deteriorating conditions. This involved lectures, tutorials, and simulation-based learning. The research component examined participants' stress responses during the simulation program. Ethical approval was granted by the Human Research Ethics Committee (Project no. 2013/740) and all participants provided written, informed consent prior to commencing the study.

Table 1
Participant demographics (n = 26).

Characteristic		n (%)
Gender		22 (85%) female
Age (mean ± SD)		33 ± 9.2 years
Position	RN	23 (89%)
	CNS	3 (12%)
Years in nursing (mean ± SD)		4.2 ± 4.7 years
Years since graduation (mean ± SD)		6.6 ± 6.1 years
Degree	Graduate certificate	4 (17%)
	Graduate diploma	6 (25%)
	Master's degree	14 (58%)
Previous simulation exposure		19 (73%)
Previous ALS training		10 (39%)
Specialty	Aged care	3 (12%)
	Medical ward	10 (38%)
	Medical-surgical ward	2 (8%)
	Surgical ward	4 (15%)
	Primary care	2 (8%)
	Other	5 (19%)

Values represented as n (%) unless otherwise stated.
Percentages may not sum to 100 due to rounding.
RN – registered nurse, CNS – clinical nurse specialist.

2.1. Participants

All post-graduate registered nurses undertaking studies in advanced clinical nursing were invited to participate in this study. Twenty-six students consented to participate. They were predominantly generalist registered nurses working in medical and surgical wards. Most had prior simulation experience, but a minority had not undertaken any previous advanced life support training (Table 1).

2.2. Procedures

All participants completed 6 h of lectures and 6 h of workshops on assessment and management of common clinical emergencies using advanced life support theory. Participants also completed a three-hour practice session of airway and cardiac resuscitation to increase technical skills prior the immersive simulations. This training was based on a previously designed clinical emergency simulation course (Gordon and Buckley, 2009). This theoretical component consisted of the early intervention and management of life-threatening conditions, specifically focussing on cardiovascular, respiratory, and neurological pathophysiology, clinical assessment and emergency management guidelines. This was followed by clinical workshops which taught technical skills related to cardiovascular and respiratory assessment and management of clinical emergency scenarios. Technical skills were practiced using Resusci Anne Simulator® and participants were assessed until competency was achieved. Evaluation was based on the advanced resuscitation guidelines from the Australian Resuscitation Council (Council, 2006).

On the day of the simulations, participants undertook a pre-briefing session and were familiarised with the high-fidelity human patient simulator (SimMan®) and the simulation setting. Participants were encouraged to explore this learning environment and ask questions to become familiar with the layout and key features. Participants were provided with safety instructions about the room (e.g. how to signal for help using emergency button and telephone). The simulation control room was adjacent to the simulation laboratory and a one-way glass

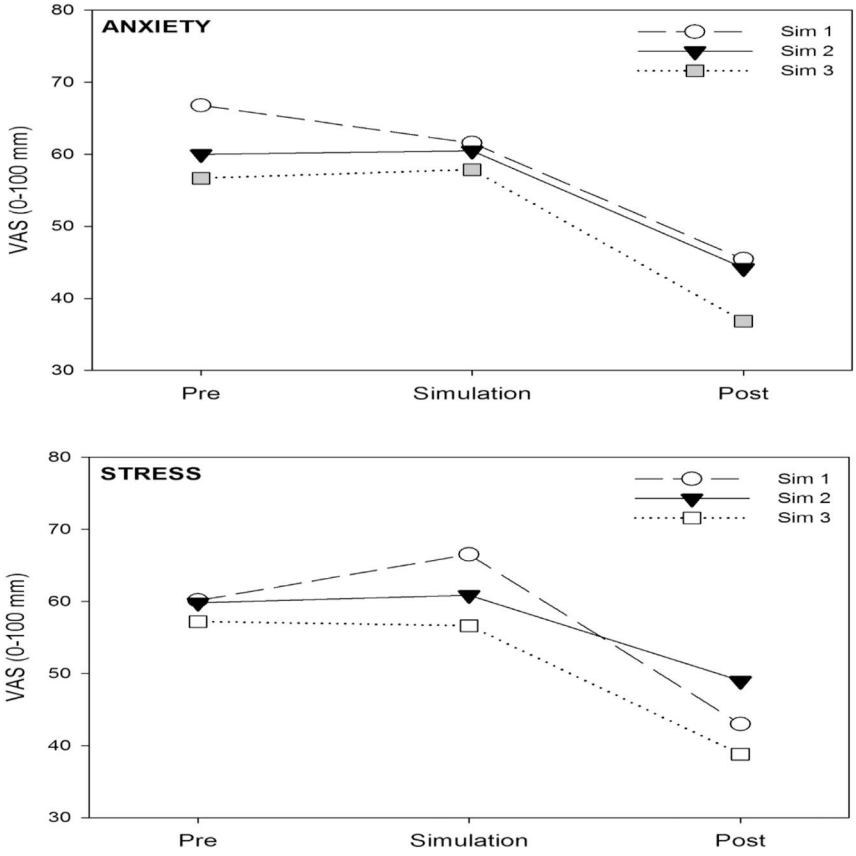

Fig. 1. Change in self-reported anxiety and stress, before, during and after the three simulations. Error bars have been removed to increase graphical clarity.

window allowed direct observation of the whole room. Audio cues from the patient simulator were provided by an experienced educator in the control room. Participants were instructed to interact with the human patient simulator as they would a real patient.

Participants were allocated to groups consisting of 5–6 students who each completed three simulation scenarios of similar difficulty. The composition of these groups did not change; however, the role the participant performed changed according to the task allocation. Participant groups entered the immersive simulation room and assessed the clinical situation of the patient. Delegation of tasks was provided by the team leader, which was determined within the group prior to the immersive simulation. The team leader allocated to airway, cardiac (external chest compressions if required), defibrillation, and medication management and scribe were combined. Participants were required to assess and resuscitate the 'patient' using advanced life support algorithms. The simulation ended when the 'patients' were resuscitated successfully. The scenarios included respiratory or cardiac arrest, either immediate or delayed. Precipitant causes of arrest varied from brain injury, electrolyte imbalances, haemorrhage, and medication hypersensitivity. Each simulation scenario lasted between 5 and 12 min and there were minimal interactions with simulation staff. Participants could telephone for assistance, alerting of an emergency, or clinical results.

Following each individual simulation scenario, participants were debriefed using video playback. An experienced simulation educator asked participants to identify team roles and what approach they instigated during the scenario. The educator facilitated discussion of performance and critical issues were discussed. Debriefing sessions ran for 15–20 min.

2.3. Instruments

Prior to the simulations, participants completed a validated trait anxiety questionnaire (Spielberger, 2010) to determine baseline levels of trait anxiety. Participants were administered a validated '*pre*' and '*post*'-simulation program questionnaire that self-assessed their ability to respond to clinical emergencies (Gordon and Buckley, 2009). This was used to determine the performance scores.

Participants were fitted with a heart rate (HR) chest strap monitor that measured continuous HR throughout the simulation scenarios. Heart rate was analysed for the 5 min prior to the simulation ('*pre*'), average and peak HR '*during*' the entire simulation scenarios (8–10 min), and HR for 5 min immediately following the simulation ('*post*').

Immediately prior to each of the three simulation scenarios ('*pre*'), participants rated their anxiety and stress levels using a 100 mm visual analogue scale (VAS) (Judd et al., 2016; Lesage et al., 2012). This involved marking on the line with opposing descriptors from 'very little' to 'very much' the amount of anxiety and stress they were experiencing. Directly following the scenario, participants rated their anxiety and stress both during the simulation and how they felt after the simulation ('*during*' and '*post*' measures). Due to conflicting literature about the possible relationship between the two constructs of anxiety and stress, both were measured in this study. In addition, participants also completed VAS rating confidence of their performance following each scenario (Liaw et al., 2011).

2.4. Data analysis

Descriptive statistics were used to characterise the participants' trait scale, HR, stress, anxiety and confidence scales, and performance measures. The change in self-reported clinical performance before and after the emergency simulation program was analysed using a Student's paired *t*-test. Linear Mixed Models were used to analyse mean differences in stress variables (HR and VAS of anxiety, stress and confidence) over time ('*pre*', '*during*', and '*post*' simulation scenario) and across the three simulation scenarios. Effect sizes were calculated using Cohen's d and were adjusted for dependent mean scores (Taylor, 2015). The following ranges were used to classify the effect magnitude: small 0.1–0.4; intermediate 0.5–0.7; large > 0.8 (Cohen, 1988). Pearson's product moment correlations were used to compare stress variables (self-reported anxiety and stress), confidence and performance. Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) version 25 and alpha was set at $p < 0.05$ for all analyses.

3. Results

The majority of participants were female registered nurses with a mean of 4.3 years of experience (Table 1). Almost three-quarters had previous simulation exposure but less than half had been exposed to ALS training. The trait anxiety at baseline was within the normal range for students (39.6 [SD 6.1]) (Spielberger, 2010).

3.1. Stress variables

Self-reported anxiety and stress, measured using a VAS, exhibited a progressive decrease in levels across the three simulation scenarios (Fig. 1). Overall, anxiety and stress prior to, and '*during*' the simulations were similar, with a dramatic decrease following the simulation completion. With one exception, mixed models revealed statistically significant differences at the '*post*' simulation time point in both self-reported anxiety and stress (anxiety: Sim 1 $p = 0.04$; Sim 2 $p = 0.003$; Sim 3 $p = 0.004$; stress: Sim 1 $p < 0.001$; Sim 2 $p = 0.051$; Sim 3 $p = 0.010$). Table 2 shows that for each scenario, there were no statistically significant differences in '*pre*' vs '*during*' mean stress or anxiety scores; however, there were differences between '*during*' vs '*post*' and '*pre*' vs '*post*'. Regarding effect sizes, the within-anxiety, and stress effect sizes between the different timepoints of the simulation ('*pre*' vs '*during*' simulation vs '*post*') were intermediate to large except for '*pre*' vs '*during*' comparisons (Table 2). Overall there was a strong association between anxiety and stress scores ($r = 0.904$, $p < 0.001$).

Table 2
Anxiety and stress effect sizes within the three simulations scenarios.
Key: Pre – before the start of the simulation; during – score given for simulation period; post – immediately after the completion of the simulation.

Variable	Time points	Cohens d	p value
Anxiety	Sim 1 pre vs during	0.19	0.363
	Sim 1 during vs post	**0.59**	**0.008***
	Sim 1 pre vs post	**0.74**	**0.001***
	Sim 2 pre vs during	0.02	0.927
	Sim 2 during vs post	**0.65**	**0.002***
	Sim 2 pre vs post	**0.60**	**0.004***
	Sim 3 pre vs during	−0.04	0.842
	Sim 3 during vs post	**0.71**	**0.002***
	Sim 3 pre vs post	**0.68**	**0.003***
Stress	Sim 1 pre vs during	0.24	0.217
	Sim 1 during vs post	**0.82**	**< 0.001***
	Sim 1 pre vs post	**0.64**	**0.002***
	Sim 2 pre vs during	−0.04	0.821
	Sim 2 during vs post	**0.46**	**0.02***
	Sim 2 pre vs post	0.39	0.059
	Sim 3 pre vs during	0.02	0.929
	Sim 3 during vs post	**0.60**	**0.008***
	Sim 3 pre vs post	**0.61**	**0.008***

Values in bold are those that reached statistical significance at $p < 0.05$.
* p value significant at $p < 0.05$.

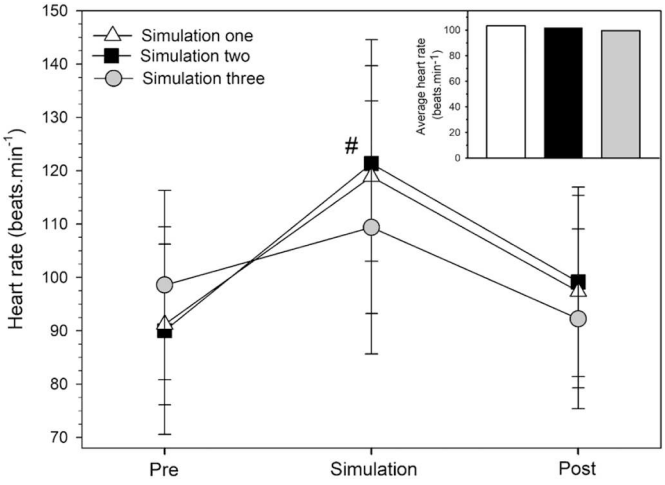

Fig. 2. The change in heart rate before, during and after repeated simulations. Simulation heart rate represents the peak value recorded during the simulation period. The average increase in heart rate is represented in the small inset bar graph. Error bars represent standard deviations. # - significant difference between peak heart rate and pre and post values.

During each of the three simulation scenarios there were statistically significant HR increases from '*pre*' levels (Fig. 2). Heart rate peaked '*during*' the simulations above the '*pre*'-anticipatory HR in the 5-minute period before the commencement of each simulation scenario. The peak HR was not statistically significantly different between the three simulation scenarios (118.9 (SD 25.7), 121.4 (SD 18.2), 109.4 (SD 23.7), all $p > 0.05$). Average HR was also elevated compared to prior to the simulation scenario, but not different between the three simulations (103.6 (SD 22.1), 101.9 (SD 18.9), and 99.5 (SD 23.4); $p > 0.05$, respectively).

3.2. Performance scores

Overall, participants reported an increase in performance after the simulation. This improvement was significantly different from baseline ('*pre*': 75.7, *SD* 12.3) to after ('*post*': 88.3, *SD* 9) the simulation program ($t(25) = 5.8$, $p < 0.001$). Previous ALS training or simulation training did not influence the increase in performance scores ($t(24) = -0.3$, $p = 0.77$; $t(24) = -0.4$, $p = 0.69$).

The confidence of participants increased progressively across the simulation scenarios, with a 37% increase between the first and last simulation (Fig. 3). The mixed model revealed that the increases in confidence were statistically significant ($p = 0.01$) with larger effect sizes between the first and second ($d = -0.40$) and first and third simulation ($d = -0.58$) than between simulation two and three ($d = -0.17$).

3.3. Heart rate, stress and confidence vs performance

Self-reported anxiety and stress during the three simulation scenarios were statistically significantly associated with performance scores (Table 3), although correlations were relatively weak. In contrast, confidence ratings during the three simulations were not consistently associated with performance scores. There were no statistically significant correlations between average or maximal HR during the simulations and the performance scores (all $p > 0.05$).

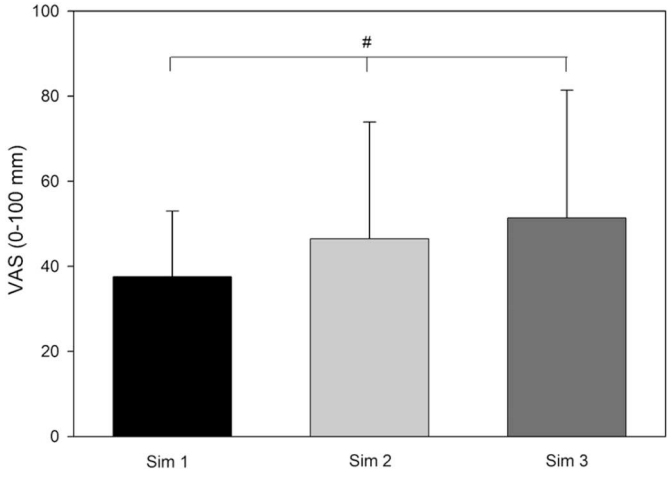

Fig. 3. Self-reported confidence during each simulation scenario. Participants rated confidence in their performance during each simulation. These were recorded immediately following the simulation scenario. $^{\#}p = 0.01$ (mixed model).

Table 3
Correlations between anxiety, stress, confidence and performance.

	Performance scores (pre-sim)	Performance scores (post-sim)
Sim 1: Anxiety	r = −0.200, p = 0.012*	r = −0.172, p = 0.032*
Sim 2: Anxiety	r = −0.198, p = 0.013*	r = −0.230, p = 0.004*
Sim 3: Anxiety	r = −0.0129, p = 0.109	r = −0.328, p < 0.001*
Sim 1: Stress	r = −0.244, p = 0.002*	r = −0.287, p < 0.001*
Sim 2: Stress	r = −0.281, p = 0.012*	r = −0.221, p = 0.006*
Sim 3: Stress	r = −0.166, p = 0.038*	r = −0.349, p < 0.001*
Sim 1: Confidence	r = 0.548, p = 0.004*	r = 0.330, p = 0.100
Sim 2: Confidence	r = 0.292, p = 0.147	r = 0.471, p = 0.015*
Sim 3: Confidence	r = 0.214, p = 0.239	r = 0.132, p = 0.507

Note: anxiety, stress and confidence were self-reported VAS during the simulation.

* p value significant at $p < 0.05$.

4. Discussion

This study is the first to demonstrate the effect of the simulation of clinical emergencies on psychophysiological stress, confidence and performance in registered nurses during repeated scenarios. We observed temporal-dependent changes in psychophysiological stress variables across the simulation scenarios, with stress, anxiety and HR increasing '*pre*' to '*during*' and then decreasing '*post*' scenario. Overall levels showing a modest decrease progressing across scenario 1, 2 and 3. Further, there were dramatic reductions in psychological and physiological stress after the simulation scenarios. This was coupled with a progressive increase in simulation confidence and overall increase in self-rated performance. The potential clinical significance of psychological stress was demonstrated with intermediate to strong effect sizes across the first two simulation scenarios (Table 2). Collectively, these data show that psychological and physiological stress exhibit different magnitudes and temporal patterns and maybe dose-dependent with confidence during the simulation and overall performance. The implications need to be understood in context for simulation-based learning, which often exposes participants to learning scenarios without consideration of the stress-performance paradigm, which strongly influences learning.

As hypothesized, self-reported confidence increased with successive scenarios. However, we observed that the increase from the second to third scenario was more modest. Interestingly, the effect sizes of the self-reported anxiety and stress were more pronounced between the first and third, and, second and third simulation scenarios. This suggests that confidence increases rapidly after simulation exposure, but stress levels may need more repeated simulation scenarios to reduce. This has implications for the design of simulation, at least simulations that involve clinical emergency situations, with at three scenarios sufficient to consolidate learning. The effects of increased confidence are a usual feature observed in simulation (Bambini et al., 2009; Nitschmann et al., 2014). Confidence is often inferred as a measure that participants are then competent, but this can be misguided. The competent-confidence paradigm is one that is often compounded, and simulation educators need to be mindful of the potential discrepancy between learning and self-reported confidence.

The level of stress experienced by participants in this study reflected a typical stressful event, with elevated scores '*during*' the simulation scenarios. This is consistent with other similar studies using VAS as stress markers in clinical or simulation environments (Judd et al., 2016; Lesage et al., 2012). The '*pre*'-scores for anxiety associated with the first simulation scenario were elevated. This may have reflected anticipatory nervousness about the simulation day and the generally the unknown events that will follow. However, 73% of participants had previous simulation experience with almost half (39%) with prior ALS experience. This suggests that despite previous experience levels, repeated scenarios are required for amelioration of elevated stress, which was related to confidence levels. Educators may consider changes to orientation and briefing to potentially alter this '*pre*'-scenario anxiety. Overall levels of stress and anxiety reduced with successive simulations, and these findings are consistent with other studies (Müller et al., 2009; Rossignol, 2017). It has been proposed that the reduced psychological anxiety on repeat exposure implies that participants perceived that personal resources were sufficient for the performance situation (Rossignol, 2017).

Heart rate was, as predicted, elevated during simulation scenarios, reflecting a stress response. This response is consistent with HR responses from simulation and clinical training (Arora et al., 2010). This pattern is similarly reflected in the VAS measures of psychological stress. By the third scenario, there was a reduced stress response from participants. This is evidenced by a lower 'post' score. Overall, it appears that three scenarios were sufficient to consolidate confidence with a concomitant reduction in psychophysiological stress response (HR and self-reported anxiety and stress). The significant increase in performance ('*pre-post*' simulation program) was associated with the anxiety and stress recorded during the first and second simulations, indicating that three scenarios was sufficient to exhibit this change in performance. However, further research could explore if a smaller number of scenarios could elicit similar performance score changes. Participants reported a significant increase in performance in the '*pre-post*' questionnaires about perceived ability to manage emergency and skills required. This improvement was despite the scenarios being recognised by participants (subjective and objective stress markers) as stressful learning experiences. This suggests that stress levels did not exceed the threshold of impacting negatively on performance.

4.1. Limitations

The design of this study did not consider what role each student was performing in each of the simulation scenarios. This may potentially have an impact on stress, although research suggests that stress levels are comparable across all roles in simulation scenarios (Dias and Scalabrini-Neto, 2017; Girzadas et al., 2009). Additionally, the findings of this study need to be replicated in other clinical environments as stress levels may not be comparable across different settings (Judd et al., 2016). Logistical constraints prevented an objective measure of student simulation performance, and this may have added another dimension to the relationship of performance to stress variables. This limitation could be addressed in future research. The sample size was relatively small, and no power analysis was undertaken to detect

specific effect sizes, which may have contributed to statistical non-significance.

5. Conclusion

This study was the first to show the interaction of stress, performance and confidence in registered nurses during simulation-based education of clinical emergency assessment and management. Results demonstrate high fidelity simulation scenarios elicit elevated stress in participants. Two simulation scenarios may be sufficient for learning outcomes as the third scenario did not significantly add to confidence.

Funding source

Nil.

Conflict of interest

None declared.

Ethical approval

This study complies with the ethical standards for human research. Data collection for this study was approved by the University of Sydney Human Research Ethics Committee (Protocol Approval 2013/740). Participants provided voluntary written consent for the study.

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