

A randomised study of the effect of external distractors on the quality of ventilation in a simulated adult cardiac arrest

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Stress is an often-attributed cause of failure of individuals within teams to deliver cardiopulmonary resuscitation (CPR) to the standard for which they have been trained.^{1,2} Stress is a vague term reflecting how individuals perceive and cope with the demands that a situation places on them.³ It is well established that clinicians find cardiac arrests and other acute situations stressful.⁴⁻⁶ Studies that have looked at the relationship between clinician stress and performance in CPR have produced mixed results. Some simulation studies have found that in high-stress environments, CPR quality is reduced,^{4,7-9} but other studies have shown that effective CPR can be accurately delivered in high-stress environments.^{10,11}

These studies used similar designs, in which participants were placed in one of two scenarios: a calm, control situation, devoid of external distractors; or a more clinical, higher “socioemotional stress” situation using multiple distractors.^{4,7,9-11} Two of these studies used the term “workload” instead of stress.^{9,11} These studies used the National Aeronautics and Space Administration Task Load Index (NASA-TLX),¹³ a well validated tool that allows researchers to measure workload, or the costs incurred to individuals when they attempt to perform tasks in certain environments. In simulation research, the environments in which performance is measured are often termed “high fidelity”. “Fidelity” has been defined as the degree to which a simulated environment reflects reality.¹⁴

We designed our study to investigate the ability of critical care staff to perform a simple task in a traditional high fidelity environment as well as in lower fidelity environments. The task set was a simulated scenario for hand ventilation of an adult patient with cardiac arrest, using a bag–valve mask. The participants were tested in a high-fidelity clinical scenario, in which simultaneous electrocardiographic interpretation and arrhythmia management were also required; and in a scenario in which they played the children’s word-guessing game, hangman.

The ventilatory performance of participants was measured. Personal workload was self-assessed using a retrospective questionnaire, based on the components that make up the NASA-TLX. We hypothesised that the hangman scenario would provide a distraction with a high mental demand, without the emotional stress burden that has been hypothesised to be encountered in the clinical scenario. This established the effect of a stressful versus a non-stressful distraction on performance and workload during simulated CPR.

ABSTRACT

Objective: To establish the role of distraction in learner performance and workload when ventilating a mannequin during a simulated cardiac arrest.

Design, setting and participants: Observational, randomised simulation study of critical care doctors and nurses, set in the critical care department of Waikato Hospital, Hamilton, New Zealand

Interventions: Participants ventilated a mannequin for 1 minute in a neutral scenario that acted as a control, before immediately continuing to ventilate the mannequin in two experimental scenarios for 2 minutes each. Scenarios included one in which participants were asked questions based on resuscitation algorithms, and one in which the participants had to play the children’s game hangman. The order of the experimental scenarios was randomised.

Main outcome measures: The primary clinical performance measure was ventilatory rate. Secondary performance measures of peak airway and mean airway pressures were also analysed. Individual workload was assessed using a questionnaire based on the National Aeronautics and Space Administration task load index.

Results: We found no significant difference in any performance variable between the three scenarios. Workload was significantly lower in the control scenario. We found no difference in workload between the clinical and hangman scenarios. Doctors and nurses performed equally. Randomisation group had no effect on performance.

Conclusions: Our study suggests that simple distractors have a potent effect on perceived clinician workload, even when performing the most simple of tasks, but may not strongly influence the objective performance of the task.

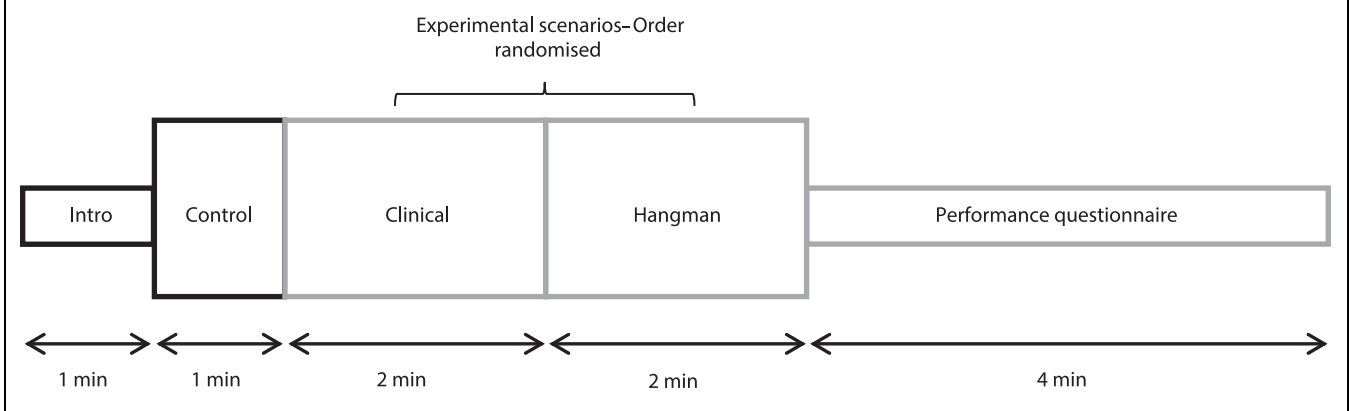
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Materials and methods

Study participants

We invited members of clinical staff from the Critical Care Department of Waikato Hospital, a tertiary referral and teaching hospital in New Zealand, to take part. Staff were invited via introductory talks that took place after daily handover meetings, and we obtained written consent from

Figure 1. 10-minute study process completed by each candidate



each participant. We conducted the study over 5 consecutive days in early September 2014. The study involved nurses and middle-grade doctors (senior house officers and registrars). The study was performed when the participants were on a clinical shift and was designed so that it would take no more than 10 minutes for each person to complete. We gained full local, Maori and Health and Disability Ethics Committee approval before commencing the study.

For a change in ventilatory rate (VR) (the primary outcome measure) from 10 to 12 breaths per minute, between the two experimental scenarios, with an α of 0.05, a study population of 32 was required. As our study had value for quality improvement in our department, and to allow for experimental failures, we aimed to recruit a study population of 40.

Most of the staff on shift during the study day took part, but the number of staff who declined to participate was not recorded. Once 40 staff had taken part, the study finished.

Experimental design

We took each participant to a newly built area of our department which, although fully completed, had not yet been commissioned for clinical use. We presented them with an intubated standard advanced life support simulation mannequin (Laerdal) lying on a standard ward bed. Attached to the endotracheal tube was a silicone adult resuscitator bag (Laerdal) without a positive end-expiratory pressure valve. We provided a standard introduction as follows.

This is your patient. I want you to imagine that they are fully monitored and they are receiving standard ICU treatments. Unfortunately your patient has suffered a cardiac arrest. You have taken them off the ventilator and your job for the next five minutes is to deliver ten breaths per minute to this patient. During this time you will be given a few 'curve balls'. I want you to imagine

other people are giving chest compressions etc. Do you have any questions?

A diagram of the study process is shown in Figure 1. Each participant was put through the three described scenarios in a single 5-minute session. Each scenario ran seamlessly with the other scenarios with no breaks in between. We gave every participant 1 minute for the introductory talk and to settle before the session started. The session started with the participant being left alone and undistracted,

Table 1. Postgraduate experience of each candidate

Years since qualification	Number of candidates (%*) (n = 38)
1-2	2 (5%)
3-4	4 (26%)
4-5	10 (16%)
6-7	6 (16%)
>8	16 (42%)

* Percentages do not add to 100 because of rounding.

Table 2. Number of occasions candidates had performed cardiopulmonary resuscitation in the 12 months before the study

Number of occasions	Number of candidates (%*) (n = 37)
0	11 (30%)
1-2	8 (22%)
3-4	6 (16%)
4-5	4 (11%)
6-7	4 (11%)
>8	4 (11%)

* Percentages do not add to 100 because of rounding.

Table 3. Outcome measures, by performance scenario

Parameter	Median (interquartile range)		
	Control	Clinical	Hangman
Ventilatory rate (breaths/min)	10.3 (8.4–14.2)	10.9 (8.7–15.3)	11.0 (9.0–15.0)
Peak inspiratory pressure (cmH ₂ O)	21.2 (14.3–27.0)	22.4 (14.3–31.2)	23.8 (16.8–32.0)
Mean airway pressure (cmH ₂ O)	2.6 (1.7–3.2)	2.5 (1.7–3.3)	2.7 (1.8–3.7)

ventilating the simulated patient for 1 minute. This acted as the control. We then put the participant through both experimental scenarios, each lasting 2 minutes, in a randomised order. At the end of the 5 minutes, we asked the participants to complete the NASA-TLX-based questionnaire and to rate the realism of each scenario. The reward for participation was a chocolate bar.

Randomisation

We randomised the order of experimental scenarios by a coin toss.

Quality of ventilation

The ventilator circuit was checked for leaks and the endotracheal tube cuff was refilled each study day. Time and airway pressures were measured using Neopuff Infant T-Piece Resuscitator equipment and software (version 2, Fisher and Paykel Healthcare). The equipment was calibrated at the beginning of each study day. The time and pressure data were recorded anonymously and transferred onto an Excel (version 14.4, Microsoft) spreadsheet, on which performance variables, VR, peak inspiratory pressure (PIP) and mean airway pressure (P_{aw}) were also calculated.

Workload

The questionnaire given to each participant was based on the six components that make up the NASA-TLX, on a graphic scale of 20 boxes. The components subjectively scored were mental demands, physical demands, temporal demands (the feeling of time pressure), total effort, frustration and achievement. Participants recorded their profession and level of experience. Questionnaires were allocated the same anonymous study number and retrospectively analysed, with scores out of 20 calculated. Participants were also asked to rate the realism of the three scenarios on an identical scale.

Figure 2. Mean performance variables expressed as box-plots. Tables show results of Mann-Whitney U tests comparing performance between the three scenarios

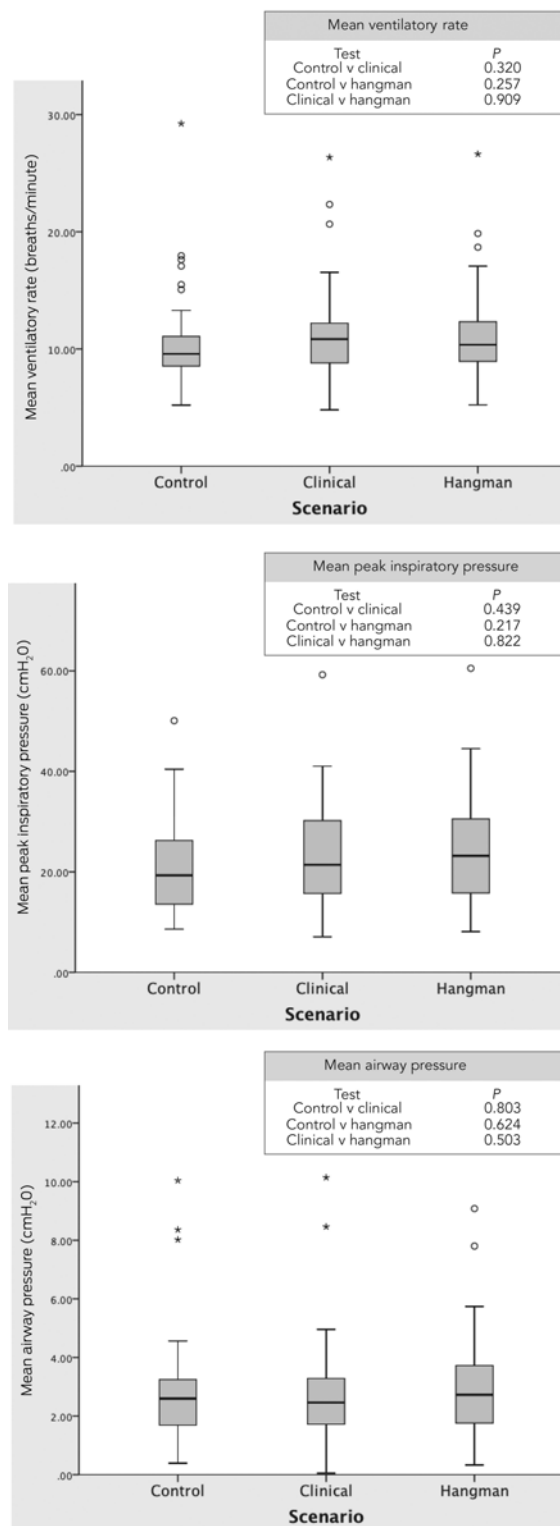


Table 4. Results of candidate workload questionnaires and realism scores

Variable	Median score (interquartile range)*			P (clinical v hangman)
	Control	Clinical	Hangman	
Mental demand	3.0 (1.0–5.0) [†]	13.0 (8.0–16.3)	12.0 (9.0–16.0)	0.916
Physical demand	2.0 (1.0–4.0) [†]	4.0 (2.0–7.25)	4.0 (2.0–7.0)	0.988
Temporal demand	3.0 (1.0–4.5) [†]	11.0 (6.8–14.3)	11.0 (6.7–14.3)	0.595
Performance	4.0 (3.0–6.5) [†]	11.0 (7.5–15.0)	10.0 (8.0–13.5)	0.606
Effort	4.0 (2.0–7.8) [†]	13.5 (9.0–17.8)	12.5 (9.0–17.0)	0.694
Frustration	3.0 (1.0–5.5) [†]	10.0 (6.5–16.0)	11.0 (6.0–16.0)	0.332
Realism	7.0 (3.5–17.5) [‡]	16.0 (14.0–20.0)	5.0 (1.0–12.0)	<0.001

* Using Wilcoxon signed-rank test, comparing workload and realism in the scenarios. † $P < 0.0167$ when control compared to both clinical and hangman.

‡ $P < 0.0167$ when control compared to clinical.

Statistical analyses

Data were collated into the spreadsheet and descriptive statistics calculated. Further statistical analyses were carried out using SPSS, version 21 (IBM SPSS Statistics for Windows). Most data did not conform to a normal distribution by the Levene test for equality of variances. Non-parametric tests (Mann–Whitney U and Wilcoxon signed-rank tests) were used. Data are therefore shown as medians with interquartile ranges. A Bonferonni-adjusted significant error rate of 0.0167 was used, as multiple tests were performed.

Results

Participant demographics

We recruited 40 participants who consented and were tested. Due to a failure of a timer during a single participant session, the ventilatory performance of 39 participants was analysed. Due to non-completion of some questionnaires, some demographic data were also missing (see Tables 1 and 2) Of the 28 nurses and 11 doctors, 36/39 (92%) had received prior advanced life support training. Clinical experience of the participants is shown in Tables 1 and 2.

Primary and secondary outcome measure

Median performance variables (VR, PIP and P_{aw}) were similar in the three scenarios (Table 3), with a trend to increasing VR and PIP in the experimental scenarios. The mean performance between the three scenarios was analysed using the Mann–Whitney U test (Figure 2). No significant difference in any performance variable was found between the three scenarios.

Participant workload

Table 4 shows participant assessment of personal workload in each scenario. It also shows the results of a Wilcoxon

signed-rank analysis of workload and clinical realism between the scenarios. Participants reported significantly lower mental, physical and temporal demands, levels of frustration and total effort in the control scenario than in either experimental scenario. Participants reported higher subjective performance in the control scenario. No significant difference between any of the NASA-TLX workload components were found between the clinical and hangman scenarios.

Further analysis using the Mann–Whitney U test found no effect of profession or randomisation group on the mean performance in each scenario (Table 5).

Discussion

VR, PIP and P_{aw} were not significantly different between the three scenarios. In the clinical and the hangman scenarios, all components of the NASA-TLX index were significantly higher than in the control scenario. We saw no significant difference in workload between the clinical and hangman scenarios, despite the clinical scenario being significantly more realistic. The order of the two experimental conditions had no effect on performance, indicating that there was no learning effect (ie, the experience gained in one scenario improved ventilatory performance in the following scenario). No significant difference was found in performance between nurses and doctors.

The performance measures show that throughout the scenarios, participants were able to deliver effective ventilation in accordance with established CPR algorithms,^{1,2} although with a large degree of variance between individual participants. These are similar findings to Bjørshol and colleagues, who found that paramedics were able to maintain resuscitation standards in a high-fidelity situation compared with a control situation, despite workload being much higher.¹⁰ Another study, with a similar design, found that

elderly lay people performed good-quality CPR in a high-fidelity environment,¹¹ but, from the literature, it should be noted that hyperventilation has been found to occur in simulation studies^{7,9,14,15} and in studies of both adult and paediatric patients in cardiac arrest.¹⁶⁻²⁰ Little research has been done into the effects of non-clinical distraction on clinical performance. Although Goodell and colleagues did not assess workload in one of their studies, they found that using mental arithmetic as a distraction significantly increased the time it took for surgical trainees to tie laparoscopic knots with a trend to increased error rate.²¹

The NASA-TLX component that assessed participant frustration correlates most closely with the classical idea of emotional stress. It is interesting that participants' perception of frustration (and all other components of the NASA-TLX) was the same between the clinical and the hangman scenario. This was surprising, as the hangman scenario was designed to act as a simple distraction. Because it is a game for children, it was intended to be a mentally demanding but low-stress distraction. There are multiple possible reasons for this. The high-fidelity situation required participants to draw on rote-learned knowledge. Perhaps some participants found accessing this information easier than "thinking on their feet" when playing hangman, but the hangman scenario may have lacked the fidelity to ensure participant "buy-in".^{22,23} Participants may have found the hangman situation so alien that that itself could have produced higher levels of workload.

We believe that ours is the first study of its kind to compare performance in CPR delivery in the presence of a realistic clinical distraction versus a more abstract one that was designed purely to distract the participants from their

primary task. Other strengths of our study were that the scenarios also ran seamlessly with each other, reflecting a dynamic CPR situation and giving the study process added fidelity. Our use of in-person questioning was also a strength, as it has been shown to reduce disruption of tasks when compared with other media (eg, telephones and hand-held devices).²³ Rather than only measuring VR, airway pressures were also analysed. An increase in either of these variables can lead to potentially deleterious hyperventilation of the patient during CPR.^{20,24}

Weaknesses of our study included the fact that participants were observed continually, which may have added an element of socioevaluative stress.³ We only studied one task of the several that contribute to the complexity of the multirole therapy of CPR. The clinical scenario used lacked some of the complexity used in other studies,^{7,9,10} and therefore could be criticised for not being truly high fidelity, but we thought that this reflected how cardiac arrests in the critical care department differ from those on wards and in the community. In critical care in general, teams are larger, tasks (ie, bag ventilations) are allocated to individuals, and bystanders (used in other studies as added external stressors)^{7,10} are not present. The fact that the participants gave the clinical scenario a high realism score supported this belief. Finally, our study was powered to detect a change of two breaths per minute in the primary outcome measure (VR), and was not powered to detect other variables that were statistically analysed.

In all, our study suggests that simple distractions during a cardiac arrest situation have a powerful effect on personal perceived workload when performing relatively simple tasks. This result may be of use to clinicians involved in CPR,

Table 5. Results of Mann–Whitney *U* test comparing mean performance variables in each scenario, by professional and randomisation groups

Performance variable	Professional group (n = 39)			Randomisation group (n = 40)		
	Doctors (n = 11)	Nurses (n = 28)	<i>P</i>	Heads (n = 17)	Tails (n = 13)	<i>P</i>
Mean ventilatory rate, breaths/min (SD)						
Control	10.40 (2.90)	10.73 (4.92)	0.885	9.94 (2.11)	11.16 (5.47)	0.955
Clinical	11.48 (3.79)	10.85 (4.79)	0.595	10.44 (2.26)	11.51 (5.57)	0.630
Hangman	10.62 (2.50)	11.49 (4.79)	0.629	11.27 (2.54)	11.20 (5.17)	0.183
Mean peak inspiratory pressure, cmH ₂ O (SD)						
Control	21.32 (11.46)	21.42 (8.88)	0.809	20.79 (7.13)	21.49 (11.14)	0.713
Clinical	20.92 (9.93)	24.6 (11.45)	0.311	23.06 (8.61)	23.33 (12.70)	0.799
Hangman	21.98 (10.46)	24.88 (11.24)	0.394	24.42 (8.62)	23.41 (12.53)	0.428
Mean peak airway pressure, cmH ₂ O (SD)						
Control	2.97 (2.46)	2.88 (1.91)	0.822	2.58 (1.65)	3.12 (2.54)	0.788
Clinical	2.95 (2.44)	2.72 (1.73)	0.923	2.53 (1.20)	2.97 (2.33)	0.887
Hangman	2.88 (2.22)	3.02 (1.73)	0.469	2.91 (1.17)	2.98 (2.45)	0.396

who may use this information to further reduce external distractors. For educationalists involved in simulation training especially, our results could be used to show students that stressors can take many forms and could be built into future simulations to encourage the development of stress-resistance strategies.^{3,25}

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Competing interest

None declared.

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References

- 1 Resuscitation Council (UK). Resuscitation guidelines 2010: adult advanced life support. London: RCUK, 2010. <https://www.resus.org.uk/resuscitation-guidelines> (accessed Aug 2015).
- 2 ACLS Training Centre. Cardiac Arrest Circular Algorithm. Scottsdale, AZ: ACLS Training Centre, 2008. <https://www.acls.net/images/algo-arrest.pdf> (accessed Aug 2015).
- 3 LeBlanc VR. The effects of acute stress on performance: implications for health professions education. *Acad Med* 2009; 84(10 Suppl): S25-33.
- 4 Hunziker S, Laschinger L, Portmann-Schwarz S, et al. Perceived stress and team performance during a simulated resuscitation. *Intensive Care Med* 2011; 37: 1473-9.
- 5 Morgan R, Westmoreland C. Survey of junior hospital doctors' attitudes to cardiopulmonary resuscitation. *Postgrad Med J* 2002; 78: 413-5.
- 6 Harvey A, Nathens AB, Bandiera G, Leblanc VR. Threat and challenge: cognitive appraisal and stress responses in simulated trauma resuscitations. *Med Educ* 2010; 44: 587-94.
- 7 Krage R, Tjon Soei Len L, Schober P, et al. Does individual experience affect performance during cardiopulmonary resuscitation with additional external distractors? *Anaesthesia* 2014; 69: 983-9.
- 8 Hunziker S, Semmer NK, Tschan F, et al. Dynamics and association of different acute stress markers with performance during a simulated resuscitation. *Resuscitation* 2012; 83: 572-8.
- 9 Bjørkli C, Øvergård K, Bjørshol C. Effects of socio-emotional stressors on ventilation rate and subjective workload during simulated CPR by lay rescuers. *Appl Ergon* 2012; 43: 799-802.
- 10 Bjørshol CA, Myklebust H, Nilsen KL, et al. Effect of socioemotional stress on the quality of cardiopulmonary resuscitation during advanced life support in a randomised manikin study. *Crit Care Med* 2011; 39: 300-4.
- 11 Neset A, Birkenes TS, Furunes T, et al. A randomized trial on elderly laypersons' CPR performance in a realistic cardiac arrest simulation. *Acta Anaesthesiol Scand* 2012; 56: 124-31.
- 12 Hart S, Staveland L. Development of NASA-TLX (task load index): results of empirical and theoretical research. In Human mental workload. Meshaki N (Ed). Hancock PA, North Holland Press, 1998; 239-50.
- 13 Paige JB, Morin KH. Simulation fidelity and cueing: a systematic review of the literature. *Clin Simul Nurs* 2013; 9: e481-9.
- 14 Bjørshol CA, Sunde K, Myklebust H, et al. Decay in chest compression quality due to fatigue is rare during prolonged advanced life support in a manikin model. *Scand J Trauma Resusc Emerg Med* 2011; 19: 46.
- 15 Niebauer JM, White ML, Zinkan JL, et al. Hyperventilation in pediatric resuscitation: performance in simulated pediatric medical emergencies. *Pediatrics* 2011; 128: e1195-200.
- 16 Olasveengen TM, Wik L, Kramer-Johansen J, et al. Is CPR quality improving? A retrospective study of out-of-hospital cardiac arrest. *Resuscitation* 2007; 75: 260-6.
- 17 Park SO, Shin DH, Baek KJ, et al. A clinical observational study analysing the factors associated with hyperventilation during actual cardiopulmonary resuscitation in the emergency department. *Resuscitation* 2013; 84: 298-303.
- 18 Losert H, Sterz F, Köhler K, et al. Quality of cardiopulmonary resuscitation among highly trained staff in an emergency department setting. *Arch Intern Med* 2006; 166: 2375-80.
- 19 Abella BS, Alvarado JP, Myklebust H, et al. Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. *JAMA* 2005; 293: 305-10.
- 20 O'Neill JF, Deakin CD. Do we hyperventilate cardiac arrest patients? *Resuscitation* 2007; 73: 82-5.
- 21 Goodell KH, Cao CGL, Schwaartzberg SD. Effects of cognitive distraction on performance of laparoscopic surgical tasks. *J Laparoendosc Adv Surg Tech A* 2006; 16: 94-8.
- 22 Weaver SJ, Rosen MA, Salas E, et al. Integrating the science of team training: guidelines for continuing education. *J Contin Educ Health Prof* 2010; 30: 208-20.
- 23 Shelton CL, Kinston R, Molyneux AJ, Ambrose LJ. Real-time situation awareness assessment in critical illness management: adapting the situation present assessment method to clinical simulation. *BMJ Qual Saf* 2013; 22: 163-7.
- 24 Aufderheide TP, Lurie KG. Death by hyperventilation: a common and life-threatening problem during cardiopulmonary resuscitation. *Crit Care Med* 2004; 32(9 Suppl): S345-51.
- 25 Petrosoniak A, Hicks CM. Beyond crisis resource management: new frontiers in human factors training for acute care medicine. *Curr Opin Anaesthesiol* 2013; 26: 699-706. □