

Recording patient data on six observation charts: An experimental comparison

Report prepared for the Australian Commission on Safety
and Quality in Health Care's program for Recognising and
Responding to Clinical Deterioration

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May 2010

Preface

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Acknowledgments

We would like to thank everyone who provided us with observation charts from their hospital or area health service for inclusion in the current study. We would also like to thank the following people for providing the de-identified patient data for use in the experiment: Imogen Mitchell and Heather McKay from The Canberra Hospital, ACT Health, and Helen Ward and Aaron Armstrong from The Prince Charles Hospital, Queensland Health.

We would also like to thank Nicola Dunbar and Alexandra Sonsie from the Commission and Lynette Adams, Kirsten Price, and Jillann Farmer from the Patient Safety Centre, Queensland Health, for their support throughout the project. We thank Paul Jackson for engineering the “Chart Roulette” software. Thanks also to members of the Royal Brisbane and Women’s Hospital for their help in recruiting participants and to staff at the Skills Development Centre, Queensland Health for their help in running the experiment, in particular James Bishop, Lisa McCoy, and Kerrilee Gow.

Finally, we thank the research assistants who helped to prepare materials and collect the data for the current study: Natasha Innes, Lachlan Rowlands, Olivia Ng, John Manly, and Nonie Finlayson.

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Executive Summary

Paper-based observation charts are the principal means of monitoring changes to patients' vital signs. There is considerable variation in the design of observation charts and a lack of empirical research on the performance of observation charts. This report describes the results of one of a series of studies carried out as part of a project funded by the Australian Commission for Safety and Quality in Health Care and Queensland Health to investigate the design and use of observation charts in recognising and managing patient deterioration, including the design and evaluation of a new adult observation chart that incorporated human factors principles. The first phase of this project involved using a procedure known as heuristic analysis to review 25 charts from Australia and New Zealand. 1,189 usability problems, which could lead to errors in recording data and identifying patient deterioration, were identified in the charts. The results from the heuristic analysis were used to design a new chart (the ADDS chart) based on human factors principles and current best practice.

In order to assess how the ADDS chart compared with a range of existing patient charts, we previously conducted a study to evaluate the performance of both novices and health professionals when using two versions of the ADDS chart (with and without a systolic blood pressure table to control for a patient's usual blood pressure) as compared with four existing charts. This study involved measuring the errors made by individuals when judging whether vital signs were normal or abnormal when they were presented on the six charts. The results indicated that those charts considered to be better designed in the initial stage of the project yielded considerably fewer errors together with shorter decision times. The two versions of the ADDS chart were found to be better than other charts (the other charts yielded between 2.5 and 3.3 times the number of errors as the ADDS charts). The absolute error rates were considerable (ranging from 9.8% for one of the ADDS charts to 32.6% for the worst-performing chart, where 50% would be chance performance).

Another stage at which error is likely to be important is when users are recording data (in the first study, the data was pre-recorded onto the charts). This report describes a second study focussed on data-recording errors, rather than decision errors. Participants recorded real patient data onto each of the six charts over an extended period in a simulated hospital ward, where they were given the task of monitoring six simulated patients (using a different chart for each patient). Each patient's vital signs were shown on a computer display by the patient's bed. The simulation was carried out in as realistic an environment as possible, including low lighting and background noise distraction. Results demonstrated that, contrary to the first study, the simplest charts yielded the fewest errors (presumably because these charts involved simply transcribing numbers from the display rather than converting the numbers into a graph, etc.). The more complex charts yielded the highest number of errors, where the two versions of the ADDS charts generated the fourth and fifth highest number of errors. However the magnitude of the error rates was much smaller than in the first study: The worst-performing chart yielded 2.3% errors, while the best-performing chart yielded 0.2% errors. That is, it appears that the process of recording data is overall far less prone to error than the process of detecting abnormal vital signs.

We aggregated data from the two studies to determine the overall error rate for each chart, taking into account both errors in recording data and errors in detecting abnormal vital signs among recorded data. Overall, the rank order found in the first experiment was maintained, because of the proportionally much higher error rates found in that study. That is, the two versions of the ADDS charts were associated with the fewest errors overall, followed by the two existing charts judged to have good designs in the heuristic analysis. The charts judged as average and poor in the heuristic analysis yielded the highest overall error rates.

These results suggest that the main errors involved in detecting deteriorating patients are likely to occur at the level of making clinical judgements rather than at the level of recording data. Chart design affects both types of error and there appears to be a trade-off between the ease of recording data and the ease of detecting deterioration, given that the charts that yielded fewer errors on detecting abnormal vital signs tended to yield more errors when data was being recorded. However, the error rates associated with recording data were much smaller than error rates associated with detecting abnormal vital signs, and hence chart design ought to focus on minimizing the latter rather than the former.

Overall, the results suggest that the ADDS charts represents an improvement over the existing charts, despite being associated with more recording errors than some of the existing charts.

1. Introduction

1.1 General background

Improving the recognition and management of patients who deteriorate whilst in hospital is a priority both at the national and state level. The Australian Commission on Safety and Quality in Health Care (ACSQHC) has launched a national program for 'Recognising and Responding to Clinical Deterioration' (1). In parallel, Queensland Health's Patient Safety Centre has released a strategy options paper discussing gaps in the recognition and management of the deteriorating patient (2).

Changes in physiological observations or 'vital signs' commonly precede serious adverse events such as cardiac or respiratory arrest, unplanned Intensive Care Unit (ICU) admission, or unexpected death (3-8). Several studies report that derangements in vital signs are observable up to 48 hours before the adverse event (3, 5, 6, 9). This suggests that if deterioration is recognised early and appropriately managed, then complications arising from delays could be reduced (e.g. morbidity, unexpected ICU admissions, extended length of stays in hospital), and some serious adverse events could potentially be avoided altogether (10-13).

Paper-based observation charts are the principal means of recording and monitoring changes to patients' vital signs. However, vital signs are not always correctly recorded or appropriately acted upon (3, 6, 9, 10, 14). The design of the observation charts themselves may contribute to failures in the ability of medical and nursing staff to record vital signs and recognise deterioration.

There is considerable variation in the design of observation charts in current use in Australia. They vary in both the number and selection of vital signs monitored. Observation charts also exhibit diversity in the way in which they display information. For instance, respiration rate may be displayed on one chart as a row containing boxes in which to write the number of breaths taken by a patient per minute at each time-point, while on another chart it may be plotted as a graph over time. Finally, observation charts also vary in the degree to which they incorporate track and trigger systems based on clinical criteria to help users recognise a deteriorating patient and respond appropriately.

There is presently a lack of empirical research on the design and use of observation charts. In Australia, observation charts tend to be designed at the local hospital or individual health service area level, resulting in a nationwide duplication of effort (10). Some observation charts appear to have been trialled in specific wards before full implementation or evaluated by means of a staff survey. Rigorous empirical evaluation is lacking in most cases.

There are indicative findings that efforts to improve the design of observation charts can produce benefits for patients, staff, and the hospital. In the United Kingdom, Chatterjee et al. carried out an empirical evaluation of 5 observation charts in use at a district general hospital (15). They reported that the design of the charts had a significant effect on the ability of staff to recognise patient deterioration (with a detection rate as low as 0% for one vital sign), and that no single existing chart was best for all vital signs. As a result, they designed and implemented a new chart incorporating a

track and trigger system. They found that there was a significant improvement in staff's ability to recognise deterioration (all detection rates over 90%), after the re-design and implementation of the new chart. Their new chart produced improvements in the detection of four forms of deterioration, hypoxia (45% increase in detection), tachypnoea (41% increase in detection), tachycardia (29% increase in detection), and fever (16% increase in detection). A recent Australian project to improve the early detection of patient deterioration, which included improvements to observation chart design (together with other interventions such as training), was found to produce statistically significant gains in the frequency of recording vital signs, as well as decreasing unplanned ICU admissions, decreasing the rate of cardiac arrests, and decreasing the rate of hospital deaths (16).

1.2 Background to the project

This project was funded by the Australian Commission for Quality and Safety in Health Care and Queensland Health to investigate the design and use of observation charts in recognising and managing patient deterioration, including the design and evaluation of a new adult observation chart that incorporated human factors principles. The initial phase of the project was a systematic usability evaluation of the quality and extent of design problems in 25 existing observation charts (17). A total of 1,189 usability problems were identified in the observation charts. Usability problems were identified as affecting the observation charts' page layout, information layout, recording of vital signs, integration of track and trigger systems, language and labelling, cognitive and memory load, use of fonts, use of colour, photocopying legibility, and night-time legibility. In compiling lists of the various usability problems present in the observation charts, principles for producing a better designed observation chart were developed.

1.3 The Adult Deterioration Detection System (ADDS) chart

Using the information obtained from the heuristic analysis, a new chart was designed by combining what were considered to be the best design features of existing charts (see reference 18 for full details). The chart was largely based on: (a) The Prince Charles Hospital chart (Brisbane, Queensland), which in turn was based on the Compass chart developed at The Canberra Hospital, and (b) the Children's Early Warning Tool (CEWT) paediatric chart developed at Royal Children's Hospital, Brisbane, Queensland). The new chart was named the Adult Deterioration Detection System (ADDS) Chart and incorporated the following features designed to minimize the design problems that might lead to human error in both recording and interpreting patient data (see Appendices A and B to view the two versions of the ADDS chart). Note that the key function of the ADDS chart was to detect patient deterioration, rather than to act as a general observation chart.

- The ADDS chart featured both a single parameter and a multiple parameter colour-coded track and trigger system to facilitate the detection of deterioration. The single parameter system (in which a medical emergency response was required when any single patient vital sign was outside a given range) had the advantage of simplicity of use. The multiple parameter system (in which vital signs were scored using a colour-coded key and scores were summed to give an overall indication of the patient's condition) was potentially more

sensitive to deterioration and could lead to earlier detection of deterioration or fewer false alarms (see reference 18 for further explanation of this issue).

- Chart colours were chosen such that colour density correlated with the extent to which the patient's vital signs were outside the normal range (apart from being an intuitive progression, this strategy would aid colour-blind users).
- All information required for use (for example, the colour key, the medical emergency criteria, and the actions to be taken when different levels of deterioration were detected) was provided on the same page as the vital signs data. This was in order to reduce cognitive load (for example, to avoid the user having to retain vital sign data in memory while turning the page to access more information).
- Terms and abbreviations used on the chart were selected in part based on the preferences expressed among a large sample of health professionals.
- Only vital signs considered to be the most important for detecting deterioration were included on the chart. If additional information had been included, this less important information would potentially compete with the more important information for the user's attention.
- Each vital sign was presented as a separate graph. Many existing charts either displayed data numerically (making it difficult to see data trends and hence making deterioration harder to detect) or included graphs with multiple vital signs plotted on the same graph area (increasing visual clutter, and potentially making deterioration harder to detect).
- The most critical vital signs were placed towards the top of the page, as this is where users would look first. Most existing charts did not follow this practice.
- Scales were labelled on both the left and right of each graph and bold vertical lines were placed every 3 columns. These features were designed to minimize the chance of users reading from the wrong column or row.
- There was space to record modifications to vital sign thresholds. This information was placed so that it would be in view when a user first picked up the chart.

1.4 Detecting abnormal vital signs study

In a previous experiment, we investigated the errors made by chart users when making a judgement as to whether a set of vital sign observations were normal or abnormal. We compared performance on six charts (two versions of the ADDS chart and four existing charts). Novices (individuals who were unfamiliar with patient charts) and health professionals (doctors and nurses) were recruited as participants. Each chart design was shown to each participant four times displaying physiological data with one abnormal vital sign (e.g. a high systolic blood pressure), and four times displaying normal physiological data. Participants had to classify the physiological data on the charts as

“normal” or “abnormal” (they were made to memorise the normal ranges for each vital sign). Error rates (the proportion of trials where participants made an incorrect normal/abnormal judgement) and response time (the time to read the chart and make the judgement) were measured.

Results indicated that chart design had a statistically significant effect on both error rates and response time, with the charts identified as having better design tending to yield fewer errors and shorter decision times. Specifically the two versions of the ADDS chart outperformed all the existing charts on both metrics, where the other charts yielded between 2.5 and 3.3 times the number of errors as the ADDS chart. There was no significant difference between novices and health professionals in error rates for any chart but the health professionals were significantly faster at making their decisions for the charts rated as “average” and “poor”. There was no significant difference between doctors and nurses on either of the two performance measures for any of the charts.

These data indicated that differences in observation chart design can have a profound impact on chart users’ decisions regarding patients’ observations as well as the time it takes to make such decisions. It appeared that the ADDS chart was substantially better than other currently available charts in this regard.

1.5 Rationale for the current study

While the previous study investigated errors made when interpreting observations that were already recorded onto a chart, errors can also be made at other stages in the process. For example, chart design could have an influence on the number of errors made when recording data onto the charts. It is conceivable (and indeed likely) that the chart designs that led to the fewest errors in detecting abnormal vital signs may not be the best charts for minimising errors made when recording data onto the charts. This is a critical stage in the process as interpretation of vital sign data will be compromised if that data is recorded incorrectly in the first place.

The present study was designed to measure errors made when recording observations onto charts under simulated hospital ward conditions. The same six charts used in the “detecting abnormal vital signs” study were compared. These included two versions of the ADDS chart and four existing charts that were chosen on the basis of ratings from the heuristic analysis: two of these charts were rated as “well designed”, one chart was rated as “average”, and one chart was rated as “poor”.

The experiment required both novices (individuals unfamiliar with using patient charts) and health professionals to record real patient data onto the six charts in an environment that simulated the conditions under which such data would be recorded in an actual hospital ward. It was hypothesized, in contrast to findings from the previous experiment, that the simpler charts might yield fewer errors at this stage. This is because the design principles applied to the more complex charts tended to be geared towards improving the detection of patient deterioration. This was often at the cost of greater effort when the data were recorded. For example, the more complex charts were more likely to involve plotting graphs and scoring vital signs for abnormalities. In contrast, the simplest charts merely required the copying of numbers directly into cells on the chart. However, we

nonetheless predicted that, among the more complex charts, those classified as being better designed in the heuristic analysis would yield fewer errors in recording data.

It was possible that the findings of this experiment could overturn the recommendations made following the previous experiment (i.e. that the ADDS chart is better than other existing charts). For instance, if the simple numerical chart yielded substantially fewer errors than the most complex charts, then this could, in principle, compensate completely for the higher error rate associated with that chart in detecting deterioration.

We also compared the performance of the novices with the health professionals (for example, it could be that different chart designs favoured different groups) and, within the health professional group, we also compared doctors and nurses.

The six charts involved in the comparison are described below.

Two versions of the ADDS chart

Two versions of the ADDS chart were included (see Appendices A and B). The first version included a systolic blood pressure table to allow the patient's usual systolic blood pressure to be taken into account when deciding the normal range for this vital sign. The second version did not have this table, and instead the normal range was based on the assumption that the patient's usual systolic blood pressure was 120mmHg. The second version was potentially simpler to read than the first version, but the first version was likely to yield a more accurate decision as to whether a patient's blood pressure was abnormal or not. Note that a minor improvement was made to the first version of the ADDS chart which had not been implemented at the time that the detecting abnormal vital signs study was conducted. Several bold horizontal lines were added to the systolic blood pressure graph to minimize row shift errors when users read across from the graph to the linked table.

Two existing charts rated as "well designed" in the heuristic analysis

Two charts were chosen because they were rated as "well designed" and were currently being widely used in Australia. Both of these charts used colour as part of a track and trigger system and displayed nearly all of the vital signs as graphs. The first chart used a single parameter track and trigger system, with two bandings of colour (yellow and red) to denote different levels of patient deterioration outside the normal range (the chart can be viewed in Appendix C). With a single parameter track and trigger system, if any vital sign was outside its normal range, this would be signalled by the data point being recorded against a coloured background, indicating that action should be taken. The second chart used a multiple parameter track and trigger system (the chart can be viewed in Appendix D). With this system, different bandings of colour (based on the severity of deterioration) were used to score each vital sign, and scores for key vital signs were summed to provide a single number summarizing the patient's overall condition. This score was used to determine the action that should be taken. The second chart (unlike the first) also used a systolic blood pressure table to allow a patient's usual systolic blood pressure to be taken into account.

One chart rated as "average" in the heuristic analysis

One chart was chosen to represent a chart of “average” quality according to the heuristic analysis (the chart can be viewed in Appendix E). The chart was monochrome and did not have a track and trigger system. Three of the key vital signs were graphed (the rest were represented numerically).

One chart rated as “poor” in the heuristic analysis

One chart was chosen to represent a chart of “poor” quality according to the heuristic analysis (the chart can be viewed in Appendix F). The chart was navy and light blue and did not have a track and trigger system. All of the key vital signs were presented as numbers rather than as graphs.

2. Method

2.1. Method Overview

The experiment took place in a simulated hospital ward (see Figure 4) containing six beds, each with a medical mannequin (the simulated patient) and a computer displaying vital signs data (see Figure 3). During one experimental session, up to seven participants (either novices or health professionals) were tested at once. The participants played the role of nurses and were given the job of monitoring the vital signs of the six patients. The seven participants rotated around the six beds (and one rest area), recording vital signs from the computer display next to each bed onto one of the paper observation charts being studied in the experiment. All participants used all six chart types (one for each of the patients under their care). Upon arriving at each bed, participants were given two minutes to record patient data displayed on the computer screen onto the given chart, before moving on to the next bed. The rotation continued until the data for eleven time points were recorded by each participant for all six patients.

2.2 Participants

A novice group ($n = 34$) and a professional group ($n = 45$) were recruited for the experiment. Novices were recruited from medical students of The University of Queensland and were paid \$50 for participating in the study. Health professionals were recruited from staff of the Royal Brisbane and Women’s Hospital and were paid \$250 for participating in the study.

2.3 Materials

The following materials were developed for use in this study.

2.3.1. Questionnaire for novice participants

Before the simulation, novice participants completed a questionnaire, asking for their age and sex as well as whether they had ever worked as a health professional, and whether they had ever used a

hospital observation chart before. They were also given the Karolinska Sleepiness Scale, which is a 9-point self-report scale of sleepiness ranging from 1 = *extremely alert* to 9 = *very sleepy, great effort to keep awake, fighting sleep*. Note that there were other questions included that were not analysed in this report. See Appendix G for the full questionnaire.

2.3.2. Questionnaire for health professionals

Before the simulation, members of the health professionals group were asked to complete a questionnaire that asked for their occupation (*nurse/doctor/other*) and further details about their nursing or medical role, including how many years they had been registered. They were also asked to record their age and sex and were also given the Karolinska Sleepiness Scale, described above. Note that there were other questions included that were not analysed as part of this report. See Appendix H for the full questionnaire.

2.3.3. Training videos

All participants viewed a number of training videos before commencing the experiment. Note that all videos are available for viewing online (please contact Mark Horswill, m.horswill@psy.uq.edu.au, for further information).

Background video: The first video covered background information required to participate in the simulation. Note that this video was different from the background video used in the “detecting abnormal vital signs” study. The purpose of the simulation (to accurately record observations on several observation charts) was explained. Participants were told that they would be responsible for a number of simulated patients whose physiological states would change over the course of the simulation (see Figure 1 for screen shots from the video, where the first panel in the figure illustrates a participant recording vital signs for a simulated patient). They were told that they would be recording eight vital signs onto a different type of observation chart for each patient (vital signs: respiration rate, oxygen saturation, oxygen delivery, blood pressure, heart rate, temperature, consciousness, and pain). Note that, unlike in the “detecting abnormal vital signs” study, the different vital signs were not explained because there were no participants without a medical or nursing background (all the novices in this study were medical students). Participants were told that a simulated medical monitor would display all eight vital signs, where the order of vital signs and the terminology used to describe them would match the particular chart being used (see Figure 1, panel 2, for a screen shot from the video depicting a mock-up of the medical monitor). The procedure for learning and practicing how to record data onto each of the different types of charts was explained next. For each chart-type, participants would be shown a video (played using custom software on a laptop - see later for full explanation) explaining how to use the chart and how to record data into it. The software would then display a series of still images (see Figure 1, panel 3), prompting participants to pick up the relevant laminated practice charts (which had two set of observations already filled in), and to complete another set of observations as displayed on the screen on a mock-up of the medical monitor. Once they had finished recording these observations, another screen showed participants what the completed chart should look like, and participants were given the opportunity to correct any errors (see Figure 1, panel 4).

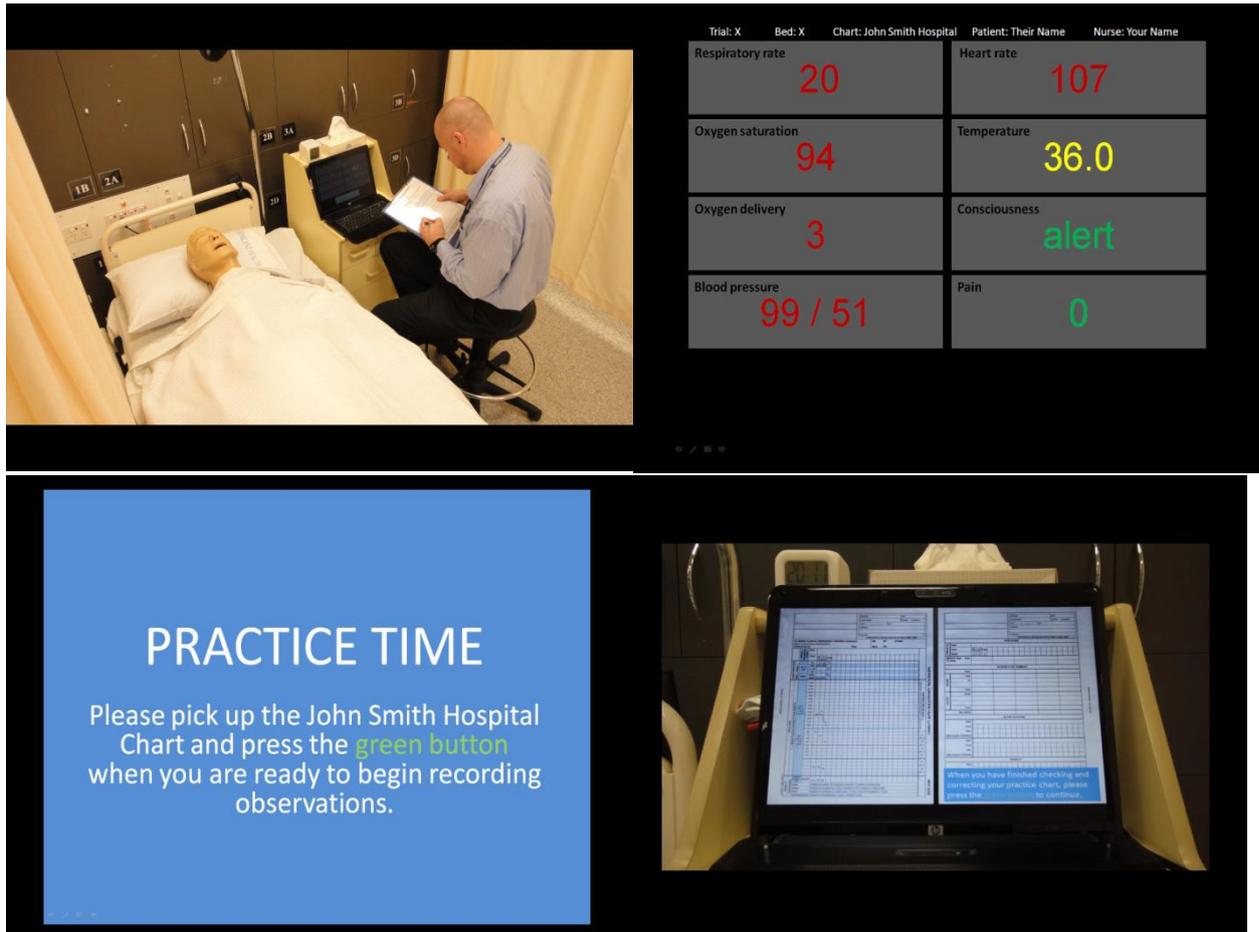


Figure 1: Four screen shots from the background information video, depicting (1) a participant filling in a chart for a simulated patient, (2) the simulated vital signs monitor display, (3) the screen used to flag when participants would practice filling in each chart, and (4) the computer displaying the relevant chart with practice data filled in correctly, to allow participants to check for errors.

Training in using each of the six charts: Five separate training modules were created for the charts used in the experiment (one for both versions of the ADDS chart and one for each of the other four charts). The training modules consisted of videos and practice schedules. The videos described how to record data onto each chart and how to interpret the charts, including explanations of cut-off scores or early warning scores, as appropriate. Custom software was used to display the training materials.

After the video for each chart was played, participants were taken to the practice schedule for that chart (see Figure 2 for screen shots from the ADDS training video). The practice schedule began with a still text image instructing them to pick up the relevant laminated practice chart (onto which two sets of observations had already been recorded). When participants pressed a green button (the left mouse button on the laptop displaying the instructions), they were shown a set of vital signs mimicking the vital sign display monitor and were required to record those observations onto the laminated chart. When they were finished, they pressed the green button to display an image of how the chart should look if the vital signs were recorded correctly. They were required to check their recorded observations against those on the screen and, if they had made any errors, they were required to correct these on the practice chart. For the ADDS chart, participants practiced with both

versions of the chart. The five chart training modules were presented in a different random order to each participant to avoid favouring some charts over others (for example, if one chart was always presented first or last then it might receive an undue advantage due to primacy or recency effects).

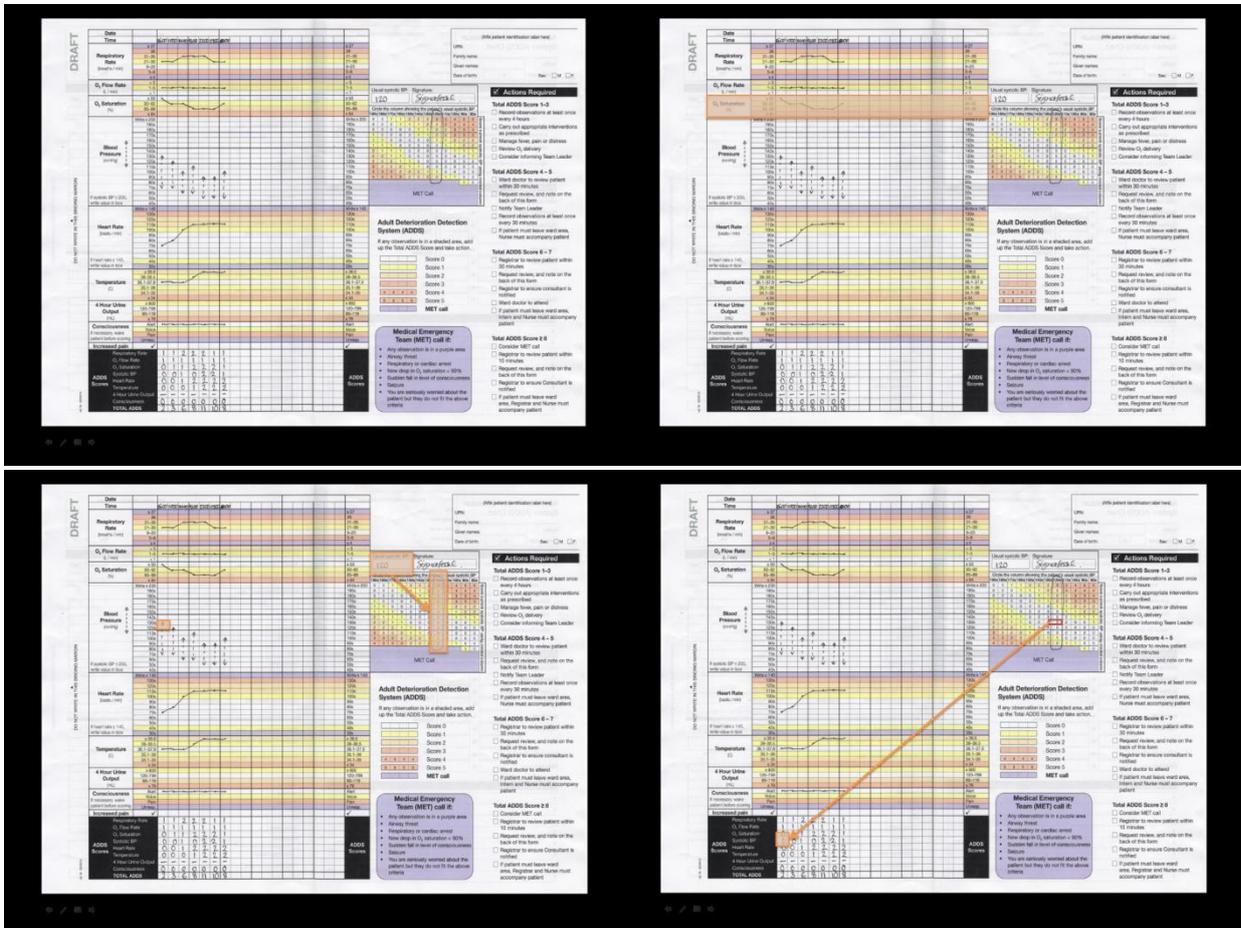


Figure 2: Screen shots taken from the ADDS chart training video, where the different aspects of the chart are highlighted while being explained by a voiceover.

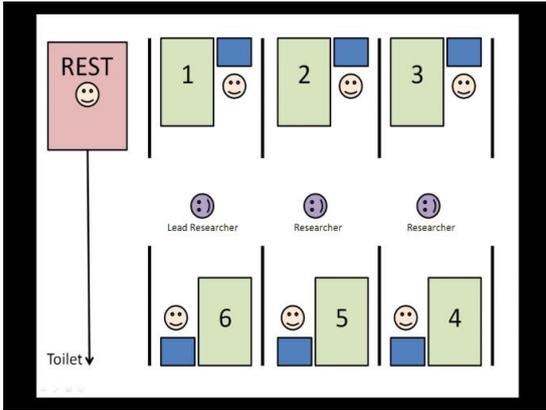
Simulation instructions video: This video described the procedure to be used in the experiment (see Figure 3 for screen shots). Participants were told that they would be moving around the six patient bays in the hospital ward simulation suite used in a clockwise direction, completing one set of observations for each of the six patients on each circuit of the ward. They were told that they would complete nine circuits of the ward in the experiment (that is, nine time points worth of data for each patient would be recorded). They were told that the lights would be dimmed and that background noise would be played to approximate the conditions that might be experienced when working in a real ward. Participants were instructed not to talk during the simulation, and were told that each circuit of the ward would include a two minute break at a rest station during which they could help themselves to refreshments or leave the room to go to the toilet.

Participants were told that they would find a holder containing several folders (each containing a chart) at the foot of each bed. They were instructed to retrieve the folder with their name on it and return to the side of the bed where the laptop that would display the vital signs was located. Participants were allowed to sit or stand to record the data. The laptop screen at this stage would

display the participant's name in large font. They were then instructed to place their hand on the forward edge of the laptop keyboard. When all participants were ready, the lead researcher would call out "Ready, set, go!" and participants would then press the space bar as quickly as possible to display the patient data for that trial, before opening their folder to begin recording data on the chart within. Participants were told always to use the pen hanging on a lanyard around their neck (which had been given to them previously). All eight vital signs were to be entered into the chart within the allotted two minutes, together with any early warning scores, including the total scores if relevant. Participants were also instructed to record the time, using either a clock positioned next to the laptop or their own watch. The two minute time progress bar at the bottom of the computer screen was also explained.

Participants were informed that after two minutes had elapsed, the lead researcher would blow a whistle and the vital signs display would be replaced by a screen signalling the end of that trial. They were then required to return the folder to the holder at the end of the bed and complete a clinical concern rating scale on a separate piece of paper, which was then posted into a box at the end of the bed. When all participants had completed this task, they were asked to move to the next bed (or to the rest station, if applicable), moving around the ward in a clockwise direction (for example, the participant at bed 6 would always move to the rest station, the participant at the rest station would move to bed 1, the participant at bed 2 would move to bed 2, and so on). Finally, participants were told that, when they had completed a full circuit of the ward and returned to the first patient that they had encountered, the vital signs for this patient would have changed and that they were to record the new data at the next time point on that patient's chart.

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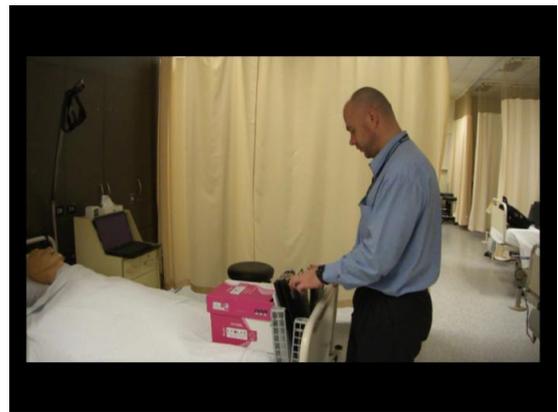
Panel 1: Schematic view of simulation suite



Panel 2: Participant at bed



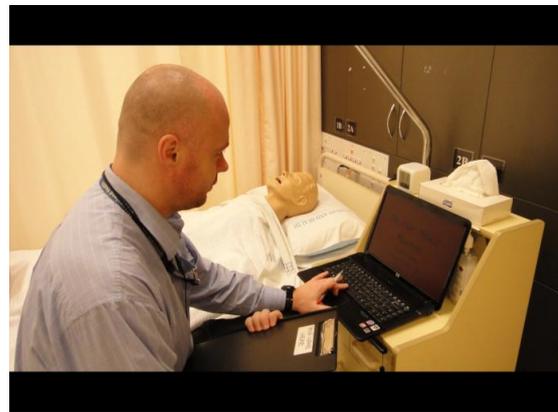
Panel 3: Participant at the rest station



Panel 4: Participant finding folder



Panel 5: Participant retrieving folder



Panel 6: Participant ready for trial

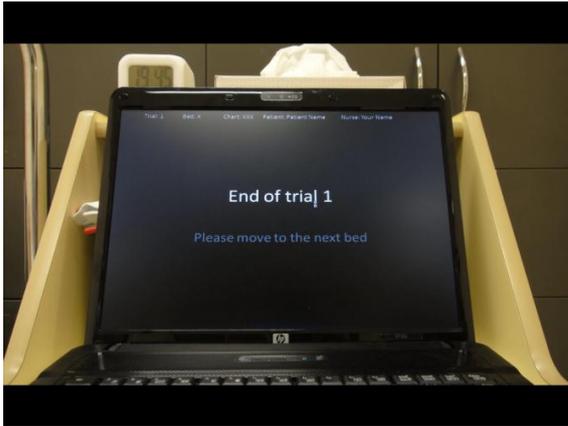


Panel 7: Participant beginning trial

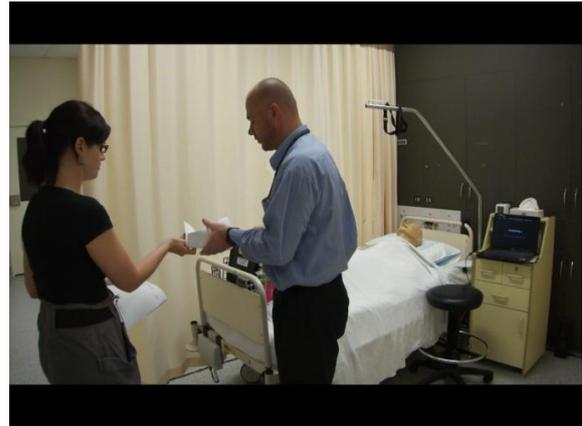
Trial: X	Bed: X	Chart: John Smith Hospital	Patient: Their Name	Nurse: Your Name
Respiratory rate	20	Heart rate	107	
Oxygen saturation	94	Temperature	36.0	
Oxygen delivery	3	Consciousness	alert	
Blood pressure	99 / 51	Pain	0	

Below the table is a progress bar consisting of 10 yellow squares.

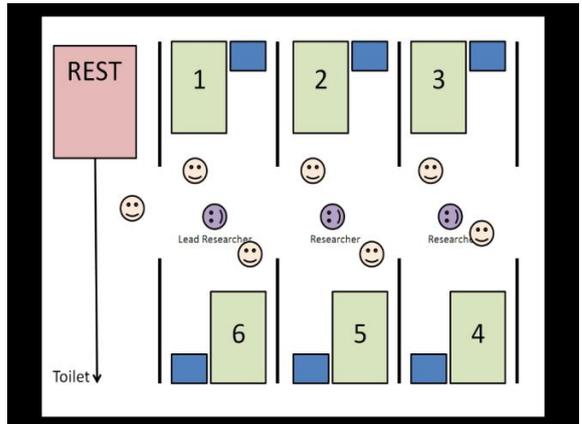
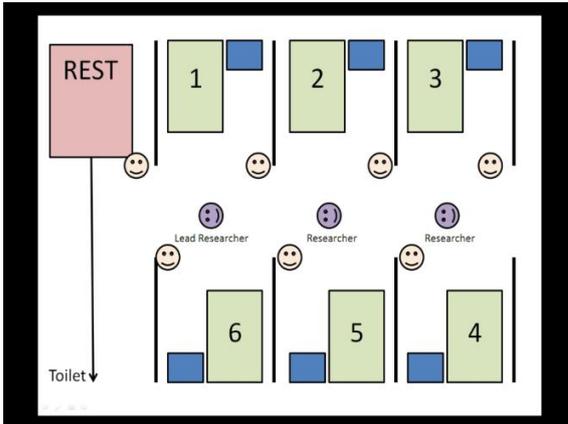
Panel 8: Simulated vital signs display



Panel 9: End of trial screen



Panel 10: Participant given rating sheet



Panels 11 to 14: Schematic view of participants moving between beds

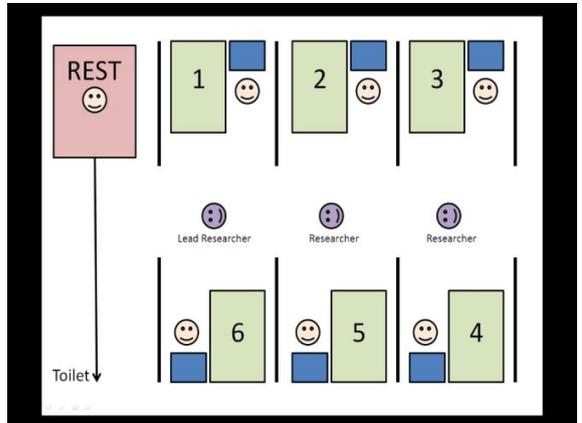
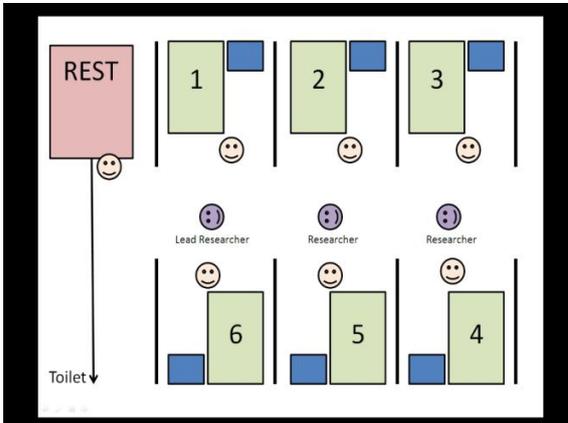


Figure 3: Screenshots taken from simulation instruction video.

2.3.4. Patient data

De-identified patient data was collected from two locations (The Canberra Hospital and The Prince Charles Hospital, Brisbane). For each patient whose observations were used in the study, data was collated for 11 consecutive time-points (the first two time points worth of data were pre-recorded onto the charts and the next nine time points were recorded by participants during the simulation).

Six of the cases obtained were used in the study. Note that these cases were different to those used in the “detecting abnormal vital signs” study because: (1) some participants took part in both experiments and so it was important that they did not recognise any cases; and (2) in comparison

with the previous study, we wanted there to be greater variability in the vital signs over time so that there was the potential for this to be reflected in the clinical concern ratings. If a data point was missing for a particular vital sign, the average of the data points from the closest available time points before and after the missing value was inserted. In addition, we made all pain and consciousness values “no pain” and “alert” respectively. Each set of patient data was assigned to one of six simulated patients (A to F), who were given fictional names for the purposes of the simulation. Details of the patient data are given in Table 1.

Table 1: Description of patient data used in the experiment.

Patient code	Description of patient data
PATIENT A	All vital signs were in the normal range: ADDS/MEWS scores = 0
PATIENT B	“Mild deterioration”: ADDS/MEWS scores 1-4. Patient had increased respiratory rate and hypotension and was receiving O ₂ at times
PATIENT C	“Immediate MET call”: Patient met the MET criteria at timepoints 1-4 during the simulation, due to very high respiratory rate and hypotension (hypotension only at time 1)
PATIENT D	“Mid-point MET call”: Patient met the MET criteria at timepoints 4-5 due to hypotension
PATIENT E	“Late MET call”: Patient met the MET criteria at timepoints 8- 9 during the simulation, due to hypotension
PATIENT F	“Moderate deterioration”: ADDS/MEWS scores 3-6. Patient had a temperature spike, tachycardia and increased respiratory rate at times

2.3.5. Vital sign display monitor simulation software

Custom software was created especially for this experiment in order to simulate a medical monitor displaying patients’ vital signs as numbers. The software was designed to run on laptop computers positioned next to the beds of the simulated patients used in the experiment. The software was designed to read a database of patient data and display this data for each trial so that it was customized to suit the type of chart being used (displaying data in the order presented on the chart and using the terminology present on that chart). This was done because the alternative – using a standard terminology and order of vital signs throughout – would inevitably have favoured some charts over others. At the beginning of the experiment, all the participants’ names were entered into the software. The software was also given information on which testing session was current (one session being an evening’s testing, with up to seven participants completing 63 trials) and to which bed the current display was assigned. From this information, the software could infer which patient was in which bed, and could also track all participants’ movements throughout the entire session, and keep track of which chart they were to use for each trial. The order of charts used by each participant (which determined which charts they used with which patient), and the bed that each

patient was located in were randomized, and were different in each session. When participants arrived at a bed, the software would display their name, the name of the simulated patient, the time point, and the name of the chart to be used. This was to minimize the chances of errors being made: this information could be checked by participants and by researchers. Pressing the spacebar started each trial (see Figure 3 for an illustration of this process). The software displayed the vital sign data for two minutes, accompanied by a progress bar at the bottom of the screen so that participants could keep track of the time elapsed. At the end of two minutes, an onscreen message told the participant to prepare to move to the next bed.

2.3.6. Preparation of charts

Six charts were evaluated in this study and are detailed in Table 2 (also described earlier).

Table 2: Descriptions of the six charts used in the experiment.

Chart	Description
1. ADDS chart with systolic blood pressure table	A new chart (the ADDS chart) developed in an earlier phase of the current project, including both single parameter and multiple parameter track and trigger systems. The format was A3 double-sided and the cut-offs for systolic blood pressure could take account of a patient's usual blood pressure (in this study, usual blood pressure was taken as 120mmHg). The chart can be viewed in Appendix A.
2. ADDS chart without systolic blood pressure table	A second version of the ADDS chart, which did not have systolic blood pressure cut-offs tailored to a participant's usual blood pressure (it assumed that usual blood pressure was 120mmHg for all patients). The chart can be viewed in Appendix B.
3. Multiple parameter track and trigger chart	A double-sided A4 chart with a multiple parameter track and trigger system. The cut-offs for blood pressure could take account of a patient's usual blood pressure (in this study, usual blood pressure was taken as 120mmHg). The chart can be viewed in Appendix D.
4. Single parameter track and trigger chart	A double-sided A3 chart with a single parameter track and trigger system, without systolic blood pressure cut-offs tailored to usual blood pressure. The chart can be viewed in Appendix C.
5. No track and trigger graphical chart	A double-sided monochrome A3 chart with no track and trigger system, where some of the vital signs were plotted as graphs but others were not. The chart can be viewed in Appendix E.
6. No track and trigger numerical chart	A single-sided A4 chart with no track and trigger system and all vital sign data written as numbers. The chart can be viewed in Appendix F.

None of the charts were modified for this experiment (unlike in the "detecting abnormal vital signs" study) and, where possible, official professionally-printed copies were obtained (Charts 3 and 4).

Data for the first two time points was plotted onto each chart by hand before the experiment by two research assistants and then double-checked.

2.3.7. The hospital ward simulation suite

The experiment was run in the hospital ward simulation suite at the Skills Development Centre at the Royal Brisbane and Women's Hospital, Queensland. This suite can be seen set up for the present study in Figure 4 (for the experiment, the curtains were drawn as in the left panel; in the right panel, the curtains are withdrawn for illustrative purposes). The simulated patients were depicted using adult medical mannequins in each of the beds (the mannequins were not actually manipulated during the experiment: they were present merely to enhance the immersive realism of the simulation for the participants). The mannequins were positioned with a pillow and blankets. Signs were placed above each bed, labelling the bed number (1 to 6) and giving the simulated patient's name and code (A to F; note that patients were randomly assigned to different beds for each session). The laptops used to show the training materials and the vital sign monitor software were positioned on tables to the right of each bed. Each of these tables also had a clock (for recording the time and date onto the charts) and a box of tissues (to allow participants to correct errors made on the laminated practice charts). At the foot of each bed, there was a holder containing seven folders labelled with participant names containing the relevant chart, and a box for posting the clinical concern rating sheets into. There was also a stool provided for the participant to sit on during each trial, if they chose to do so.

A rest station was set up at one end of the room (sectioned off with curtains), in which there were refreshments and magazines for the use of participants during rest breaks.

During the simulation, the lights were dimmed to simulate a night-time ward with low lighting. Light levels were measured at each bedside off of a white sheet of paper using a Konica Minolta LS 110 luminance meter. The average light level was 16.33 cd/m².



Figure 4: Hospital ward simulation suite with curtain drawn as in the experiment (left panel) and without curtains for illustrative purposes (right panel).

2.3.8. The background noise distracter track

To mimic the type of distracting background noise that might be present in a real ward, a five hour recording was created and played from a digital audio player via six pairs of stereo speakers (each bed was set up with a pair of speakers, where one speaker was placed on each side of the bed). The recording was a mix of people coughing and footsteps, together with a radio documentary (the radio documentary was edited to avoid music: only the voices of two presenters were heard). The sound level was chosen to be consistent with normal speech and was measured using a Bruel and Kjaer 2603 sound pressure meter. The sound level of the background noise distracter track was in the range 44 dB to 56 dB, at the location where participants would stand or sit in each patient bay.

any of the charts or the research in general. In addition, they were given the Karolinska Sleepiness Scale again, in order to check that the simulation induced a measurable effect of fatigue.

2.4 Design and procedure

The study was granted ethics approval by the Royal Brisbane and Women's Hospital's Human Research Ethics Committee and by The University of Queensland's School of Psychology Ethics Review Officer. All participants were tested in the hospital ward simulation suite at the Skills Development Centre, Royal Brisbane and Women's Hospital, Queensland, Australia.

Up to seven participants were tested during any one session by a team of four: the Project Manager, the lead researcher, and two other researchers. The Project Manager's job was to oversee the set up and conduct of the experiment. The lead researcher co-ordinated the running of the simulation (for example, blowing a whistle when a trial was complete, keeping track of which trial was being run using a flipchart, and indicating when each trial would start). The lead researcher and the two other researchers were given responsibility for monitoring two beds each. They were required to trigger the software to shift between trials, hand the clinical concern rating sheets to participants, and monitor participants to ensure that correct procedures were being followed.

Detailed instructions for the researchers can be viewed in Appendix J. Each session was run through one evening, starting at 6:00pm and ending at about 10:00 pm. When the participants arrived, they were given name labels to wear and guided to one of the beds (or, for the seventh participant, to the rest station). Participants completed consent forms before filling in the preliminary questionnaire. Novices and health professionals were tested in the same sessions in this experiment.

After filling in the questionnaire, participants were instructed to put on headphones and watch the training materials on the laptops by each bed. Once the training was complete, participants were given the opportunity to have a break before being given a pen on a lanyard for filling in the charts. The vital signs display software was started and participants' names were entered.

When all information was verified and all checks complete, the simulation began, as described above (under "simulation instructions").

Once the 63 trials ((6 patients + 1 rest area) x 9 time points = 63) were completed, participants were asked to complete the post-experiment questionnaire and were then thanked for their participation and paid.

2.5 Data analysis

The data that participants recorded into each chart was coded for errors using a transparent template. These errors were entered into Microsoft Excel 2007 and aggregate data was then exported into SPSS for Windows version 17 for statistical analysis.

3. Results

3.1 Participant characteristics

The novice group consisted of medical students from The University of Queensland (n = 34). The health professionals consisted of both doctors and nurses recruited from the Royal Brisbane and Women's Hospital (n = 44). Characteristics of the two groups are listed in Table 3.

Table 3: Participant characteristics of the two groups.

	Novices (n = 34)	Health professionals (n = 44)
Age in years	26.0 (3.8) ^a	30.5 (8.1) ^a
Gender	Female: 38.2% Male: 61.8%	Female: 72.7% Male: 27.3%
Health profession	-	Doctor: 45.5% Nurse: 54.5%
Years registered	-	Doctor: 1.9 (1.6) ^a Nurse: 2.4 (2.1) ^a

Note. ^aValues are mean (standard deviation)

3.2 Sleepiness check

The participants reported they were significantly more sleepy at the end of the simulation (Karolinska Sleepiness Scale: mean = 5.30, standard deviation = 1.60; approximately equating to the label *neither alert nor sleepy*) compared with the start (Karolinska Sleepiness Scale: mean = 3.68, standard deviation = 1.43; approximately equating to the label *rather alert*), $t(76) = 8.91$, $p < 0.001$. This suggests that the simulation session significantly affected participants' levels of alertness as intended.

3.3 Errors made in recording vital signs

The number of errors made in recording data into a single chart by each participant was divided by the total possible number of errors (= 9 time points x 8 vital signs = 72) to obtain an error rate and then multiplied by 100 to obtain a percentage. Data are presented in Figure 6.

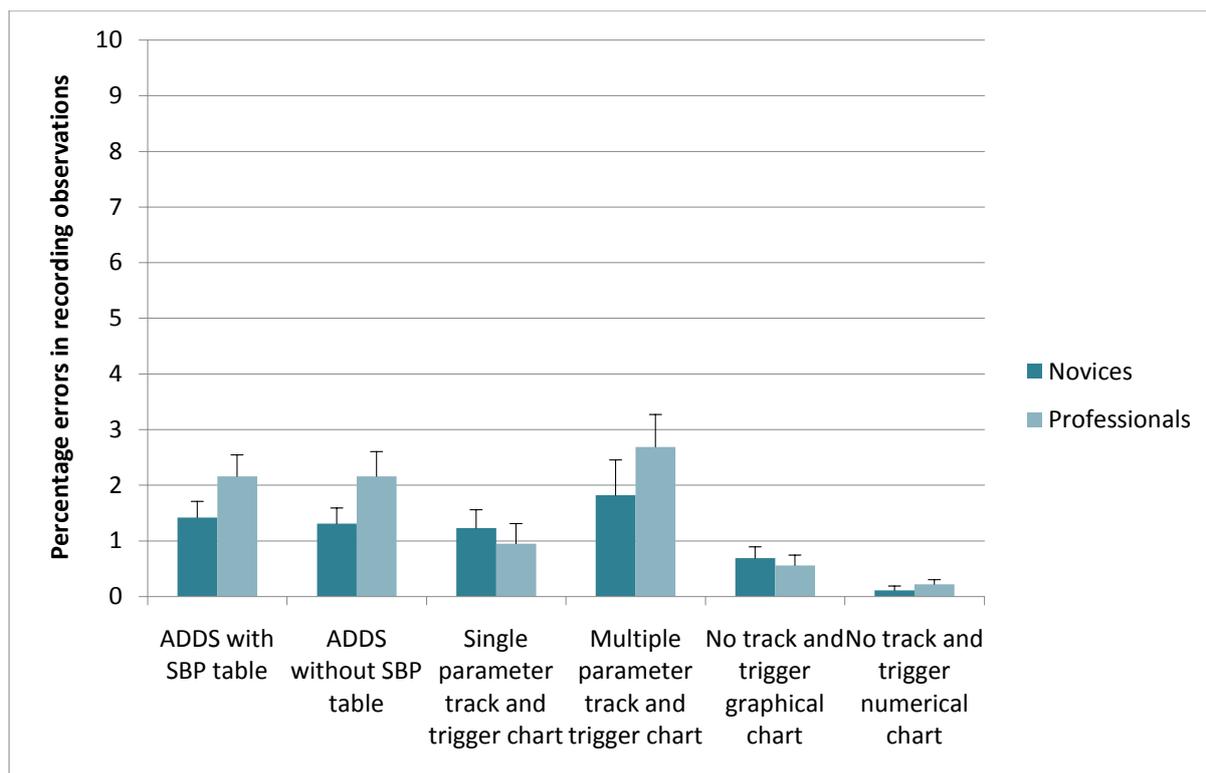


Figure 6: Percentage of recording errors made on the six charts (error bars are standard errors of the mean). Note, SBP = systolic blood pressure.

A mixed design analysis of variance was conducted, with chart type entered as a repeated-measures independent variable, novice/professional entered as a between-subjects variable, and percentage errors entered as the dependent variable. Mauchly's Test of Sphericity indicated a significant departure from sphericity (Mauchly's $W = 0.19$, $p < 0.001$) and so Greenhouse-Geisser degrees of freedom are used to interpret the repeated-measures effects. There was a main effect of chart type, $F(3.13, 237.63) = 10.54$, $p < 0.001$, but no significant difference between novices and health professionals, $F(1,76) = 1.63$, $p = 0.205$, and no significant interaction between chart type and participant group, $F(3.13, 237.63) = 1.16$, $p = 0.328$. There were no significant differences between novices and health professionals for any of the charts individually and therefore for the remaining statistics, these two groups have been combined.

Chart simple effects were investigated using t-tests, using a Bonferroni-Holm adjustment to correct for multiple comparisons, and can be viewed in Table 3. Note however that because there was positive skew in the error rate data, we also ran the comparisons in Table 4 using non-parametric tests. The pattern of results was the same except that two additional comparisons became significant. These were: (a) Single parameter track and trigger chart vs. Multiple parameter track and trigger chart and (b) Single parameter track and trigger chart vs. ADDS with systolic blood pressure table.

Table 4: Comparisons between charts on the percentage of errors recordings observations.

Comparison	Observed p	Critical p for significance at 5% level	Comparison significant at 5% level?
No track and trigger numerical chart vs. ADDS with SBP table	< 0.001	0.003	Significant
No track and trigger numerical chart vs. ADDS without SBP table	< 0.001	0.004	Significant
No track and trigger numerical chart vs. Multiple parameter track and trigger chart	< 0.001	0.004	Significant
No track and trigger graphical chart vs. ADDS with SBP table	< 0.001	0.004	Significant
No track and trigger graphical chart vs. Multiple parameter track and trigger chart	< 0.001	0.005	Significant
No track and trigger graphical chart vs. ADDS without SBP table	< 0.001	0.005	Significant
No track and trigger numerical chart vs. Single parameter track and trigger chart	< 0.001	0.006	Significant
No track and trigger numerical chart vs. No track and trigger graphical chart	0.01	0.006	Significant
Single parameter track and trigger chart vs. Multiple parameter track and trigger chart	0.01	0.007	Not significant
Single parameter track and trigger chart vs. ADDS with SBP table	0.03	0.008	Not significant
Single parameter track and trigger chart vs. ADDS without SBP table	0.03	0.010	Not significant
No track and trigger graphical chart vs. Single parameter track and trigger chart	0.06	0.013	Not significant
Multiple parameter track and trigger chart vs. ADDS without SBP table	0.28	0.017	Not significant
Multiple parameter track and trigger chart vs. ADDS with SBP table	0.30	0.025	Not significant
ADDS with SBP table vs. ADDS without SBP table	0.88	0.050	Not significant

Note. SBP = systolic blood pressure.

We divided the health professional group into doctors and nurses and found a significant main effect of profession, $F(3.07, 129.27) = 7.30$, $p < 0.001$ (sphericity was significant, Mauchly's $W = 0.16$, $p < 0.001$, so Greenhouse-Geisser adjustment reported). The nurses committed significantly more errors than doctors overall. The differences are graphed in Figure 7.

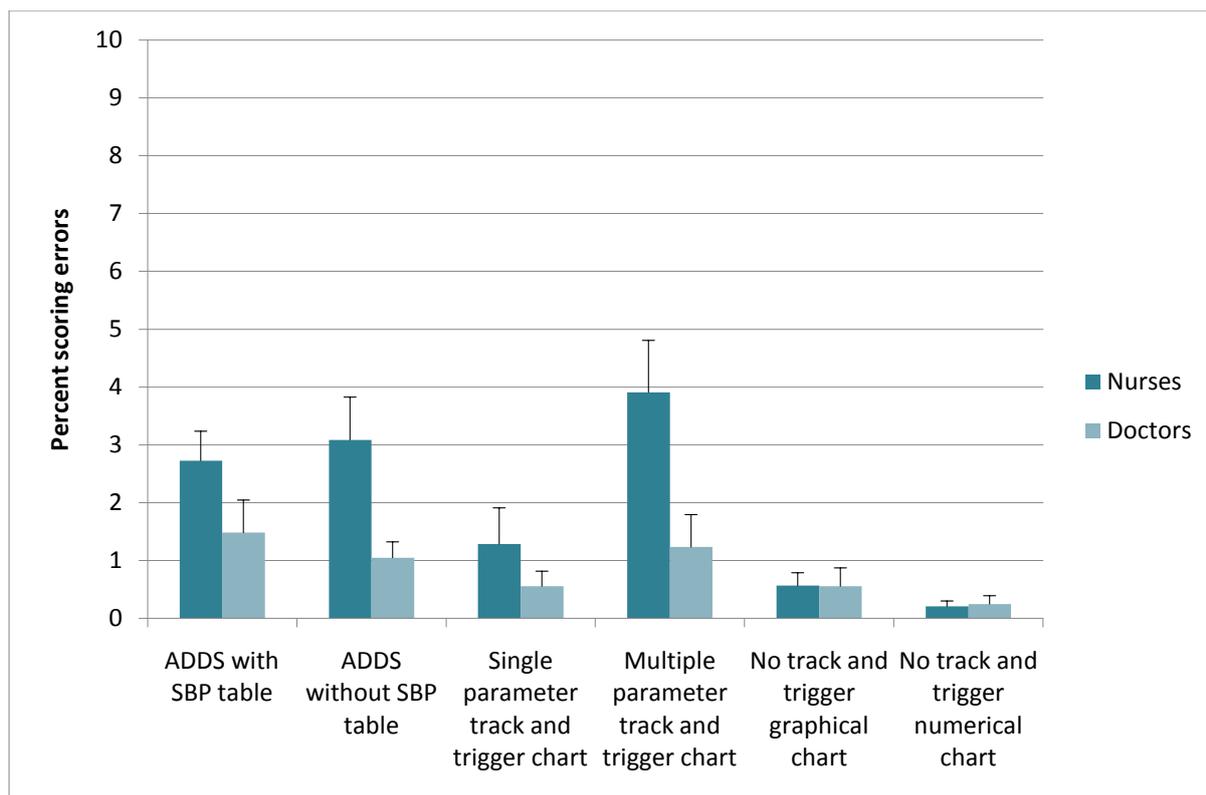


Figure 7: A comparison of doctors and nurses for percentage of errors in recording observations (error bars are standard errors of the mean). Note, SBP = systolic blood pressure.

However, multiple comparisons (using Bonferroni-Holm adjustments) indicated that, while there was a collective difference across the charts, the doctor/nurse difference was not significant for any chart individually, as shown in Table 5 (this pattern of results was also replicated when non-parametric tests were applied).

Table 5: Comparisons between doctors and nurses for errors recording vital signs.

Chart	Observed p	Critical p for significance at 5% level	Comparison significant at 5% level?
ADDS without SBP table	0.02	0.008	Not significant
Multiple parameter track and trigger chart	0.02	0.010	Not significant
ADDS with SBP table	0.11	0.013	Not significant
Single parameter track and trigger chart	0.32	0.017	Not significant
No track and trigger numerical chart	0.81	0.025	Not significant
No track and trigger graphical chart	0.98	0.050	Not significant

Note. SBP = systolic blood pressure.

3.4 Errors made when scoring multiple parameter track and trigger systems

Three of the charts had multiple parameter track and trigger systems (the two versions of the ADDS chart and the existing multiple parameter track and trigger system chart). These systems involved participants having to score each vital sign according to a colour key and combine the scores to

obtain an overall score that represented the patient's physiological state at that time point. This section documents the errors made by participants in scoring these systems. There was a maximum of 72 possible errors that could be made ((7 vital signs + 1 total score) x 9 time points) on the ADDS charts and 63 possible errors that could be made ((6 + 1 total score) x 9 time points) on the multiple parameter track and trigger chart. Error rates were calculated by dividing the total number of errors on a chart by the total number of opportunities for error (i.e. 72 or 63) and multiplying by 100 to obtain a percentage. The means are shown in Figure 8.

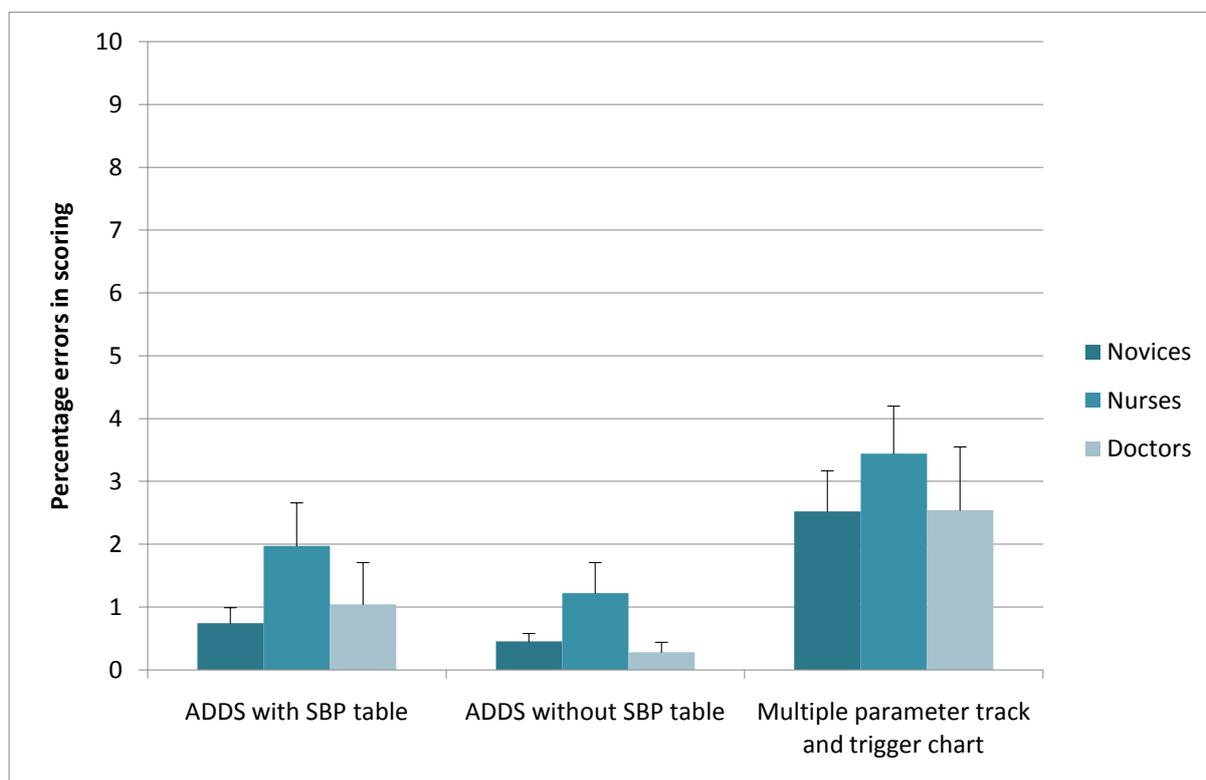


Figure 8: Percent errors made when scoring multiple parameter track and trigger systems (error bars are standard errors of the mean). This only includes errors introduced at the scoring stage; that is, transmission errors due to incorrectly plotted vital sign data were excluded. Note, SBP = systolic blood pressure.

A mixed design analysis of variance was conducted, with chart type entered as a repeated-measures independent variable, novice/nurse/doctor entered as a between-subjects variable, and percentage errors in scoring entered as the dependent variable. Mauchly's Test of Sphericity indicated a significant departure from sphericity (Mauchly's $W = 0.70$, $p < 0.001$) and so Greenhouse-Geisser degrees of freedom are used to interpret the repeated-measures effects. There was a main effect of chart type, $F(1.54, 115.67) = 11.79$, $p < 0.001$, and the differences between the three groups were not significant, $F(2,75) = 2.62$, $p = 0.08$. There was no significant interaction between chart type and participant group, $F(3.09, 115.67) = 0.07$, $p = 0.98$ (that is, one group did not commit more errors on a particular type of chart compared with the others).

The differences between the three individual charts for scoring errors were investigated using multiple comparisons (see Table 6), controlling for error inflation using a Bonferroni-Holm adjustment (and the same pattern of results was found when non-parametric tests were conducted).

Table 6: Comparisons between charts on the percentage of scoring errors (for the three charts with a scoring system).

Comparison	Observed p	Critical p for significance at 5% level	Comparison significant at 5% level?
Multiple parameter track and trigger chart vs. ADDS without SBP table	< 0.001	0.017	Significant
Multiple parameter track and trigger chart vs. ADDS with SBP table	0.004	0.025	Significant
ADDS with SBP table vs. ADDS without SBP table	0.088	0.050	Not significant

Note. SBP = systolic blood pressure.

The multiple parameter track and trigger chart yielded more scoring errors than either ADDS chart, which did not differ from one another.

Next, we subdivided scoring errors into the most common types: (a) errors in recording the appropriate MEWS or ADDS score for each of the individual vital signs, (b) errors in adding the scores for the individual vital signs to compute the overall MEWS or ADDS score for the patient, and (c) missing values, where participants had left a scoring cell on the chart blank. Note that there were other occasional errors (for example, recording individual vital sign scores into the wrong row) but the frequency of these errors was too low to yield meaningful analysis. The number of errors in each case was divided by the total number of opportunities for the error in question in a given chart. For example, there were nine opportunities per chart to make an addition error (one for each of the nine time points) so the total number of errors that one participant made on a single chart was divided by nine.

Figure 9 shows the percentage errors introduced by scoring individual vital signs. A mixed design analysis of variance was conducted, with chart type entered as a repeated-measures independent variable, novice/nurse/doctor entered as a between-subjects variable, and percentage errors in scoring entered as the dependent variable. Mauchly's Test of Sphericity indicated a significant departure from sphericity (Mauchly's $W = 0.69$, $p < 0.001$) and so Greenhouse-Geisser degrees of freedom are used to interpret the repeated-measures effects. There was a main effect of chart type, $F(1.53, 114.65) = 10.01$, $p < 0.001$, and the differences between the three groups were not significant, $F(2,75) = 1.84$, $p = 0.17$. There was no significant interaction between chart type and participant group, $F(3.06, 114.65) = 1.53$, $p = 0.93$ (that is, one group did not commit more errors in scoring individual vital signs on a particular type of chart compared with the others).

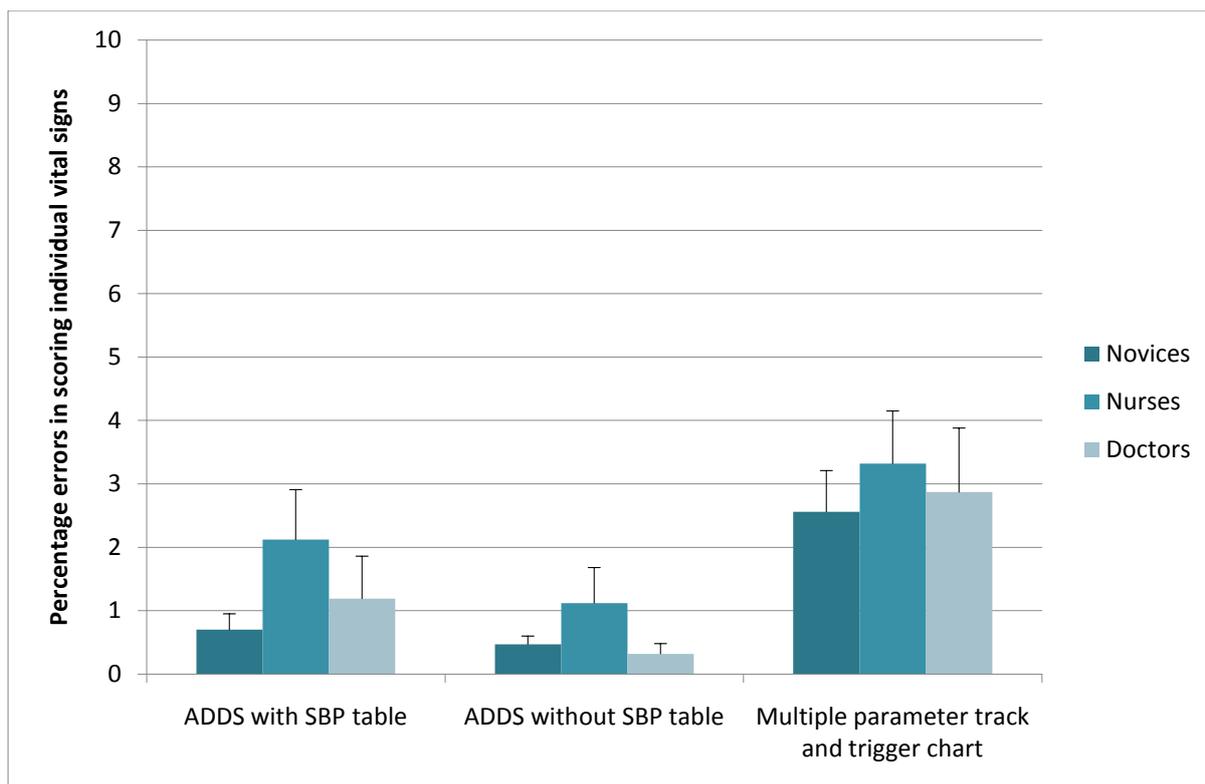


Figure 9: Percentage errors made when scoring the individual vital signs when using multiple parameter track and trigger systems (error bars are standard errors of the mean); that is, excluding errors involving computing the total aggregate score or missing values etc. Note, SBP = systolic blood pressure.

The differences between the three individual charts for errors in scoring individual vital signs were investigated using multiple comparisons (see Table 7), controlling for error inflation using a Bonferroni-Holm adjustment (the same pattern of results was found when non-parametric tests were conducted).

Table 7: Comparisons between charts on the percentage of errors in scoring individual vital signs (for the three charts with a scoring system).

Comparison	Observed p	Critical p for significance at 5% level	Comparison significant at 5% level?
Multiple parameter track and trigger chart vs. ADDS without SBP table	< 0.001	0.017	Significant
Multiple parameter track and trigger chart vs. ADDS with SBP table	0.009	0.025	Significant
ADDS with SBP table vs. ADDS without SBP table	0.077	0.050	Not significant

Note. SBP = systolic blood pressure.

The multiple parameter track and trigger chart yielded more individual vital sign scoring errors than either ADDS chart, which did not differ from one another.

Figure 10 shows the percentage of errors introduced by incorrectly adding up the scores from individual vital signs to compute the overall score for a patient. A mixed design analysis of variance was conducted, with chart type entered as a repeated-measures independent variable, novice/nurse/doctor entered as a between-subjects variable, and percentage addition errors entered as the dependent variable. Mauchly's Test of Sphericity indicated a significant departure from sphericity (Mauchly's $W = 0.40$, $p < 0.001$) and so Greenhouse-Geisser degrees of freedom were used to interpret the repeated-measures effects. There was a main effect of chart type, $F(1.25, 93.57) = 4.73$, $p = 0.01$, and the differences between the three groups were not significant, $F(2,75) = 2.35$, $p = 0.10$. There was no significant interaction between chart type and participant group, $F(2.50, 93.57) = 1.21$, $p = 0.31$ (that is, one group did not commit more addition errors on a particular type of chart compared with the others).

It is worth noting that doctors collectively made no addition errors at all in this experiment, yielding no variance for analysis. The lack of a significant group difference therefore ought to be treated with caution, as parametric test assumptions are clearly being violated. We therefore analysed the group differences (for all charts) using Mann-Whitney non-parametric tests, with a Bonferroni-Holm correction for multiple comparisons and this indicated that doctors committed significantly fewer errors than nurses and novices (who did not differ from one another).

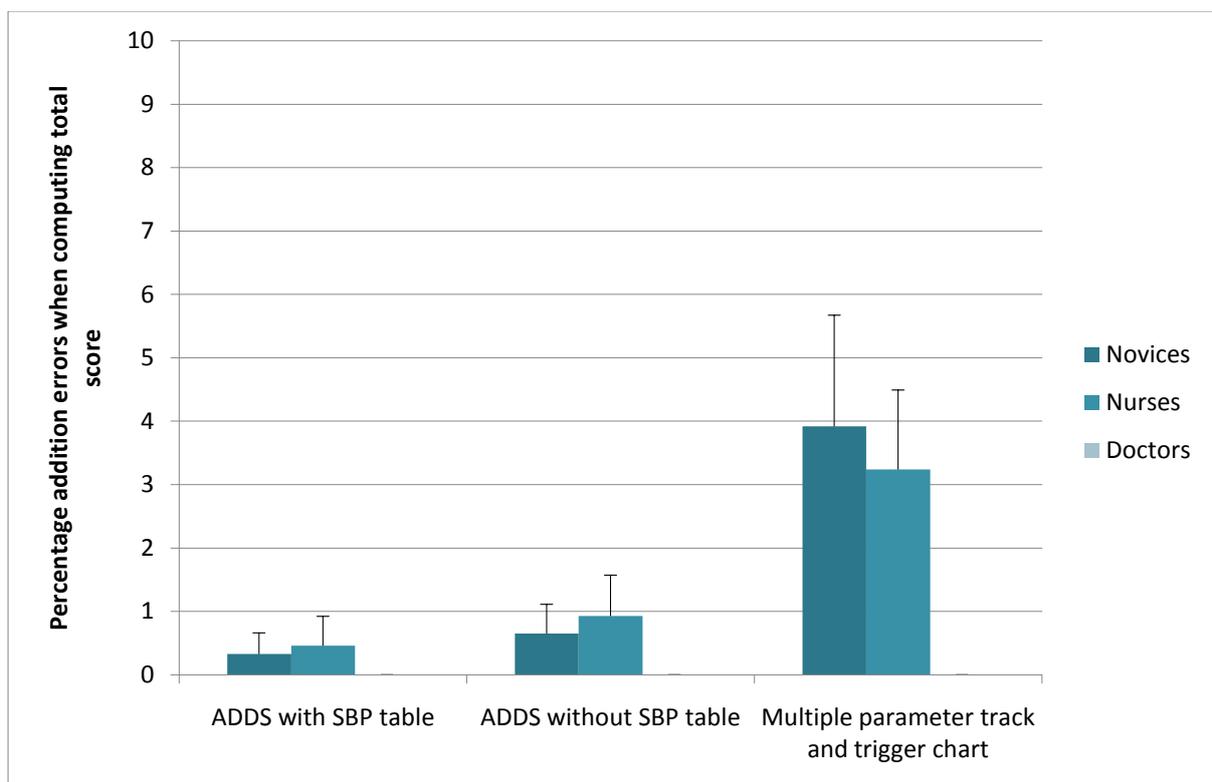


Figure 10: Percentage errors made when adding up the scores for individual vital signs to compute the overall ADDS or MEWS score when using multiple parameter track and trigger systems (error bars are standard errors of the mean). Note that the doctors in the sample generated no addition errors at all. Also note, SBP = systolic blood pressure.

The differences between the three individual charts for addition errors were investigated using multiple comparisons (see Table 8), controlling for error inflation using a Bonferroni-Holm adjustment (the same pattern of results was found when non-parametric tests were conducted).

Table 8: Comparisons between charts on the percentage of addition errors (for the three charts with a scoring system).

Comparison	Observed p	Critical p for significance at 5% level	Comparison significant at 5% level?
Multiple parameter track and trigger chart vs. ADDS without SBP table	0.009	0.017	Significant
Multiple parameter track and trigger chart vs. ADDS with SBP table	0.013	0.025	Significant
ADDS with SBP table vs. ADDS without SBP table	0.418	0.050	Not significant

Note. SBP = systolic blood pressure.

The multiple parameter track and trigger chart yielded more addition errors than either ADDS chart, which did not differ from one another.

Figure 11 shows the percentage errors introduced by missing values (where participants left a scoring cell blank). A mixed design analysis of variance was conducted, with chart type entered as a repeated-measures independent variable, novice/nurse/doctor entered as a between-subjects variable, and percentage missing values entered as the dependent variable. Mauchly's Test of Sphericity indicated a significant departure from sphericity (Mauchly's $W = 0.87$, $p = 0.006$) and so Greenhouse-Geisser degrees of freedom were used to interpret the repeated-measures effects. There were no significant effects at all (chart type, $F(1.77,132.90) = 0.58$, $p = 0.54$, group effect, $F(2,75) = 0.14$, $p = 0.87$; interaction, $F(3.54,132.90) = 1.01$, $p = 0.40$). Non-parametric tests on both main effects also yielded no significant differences.

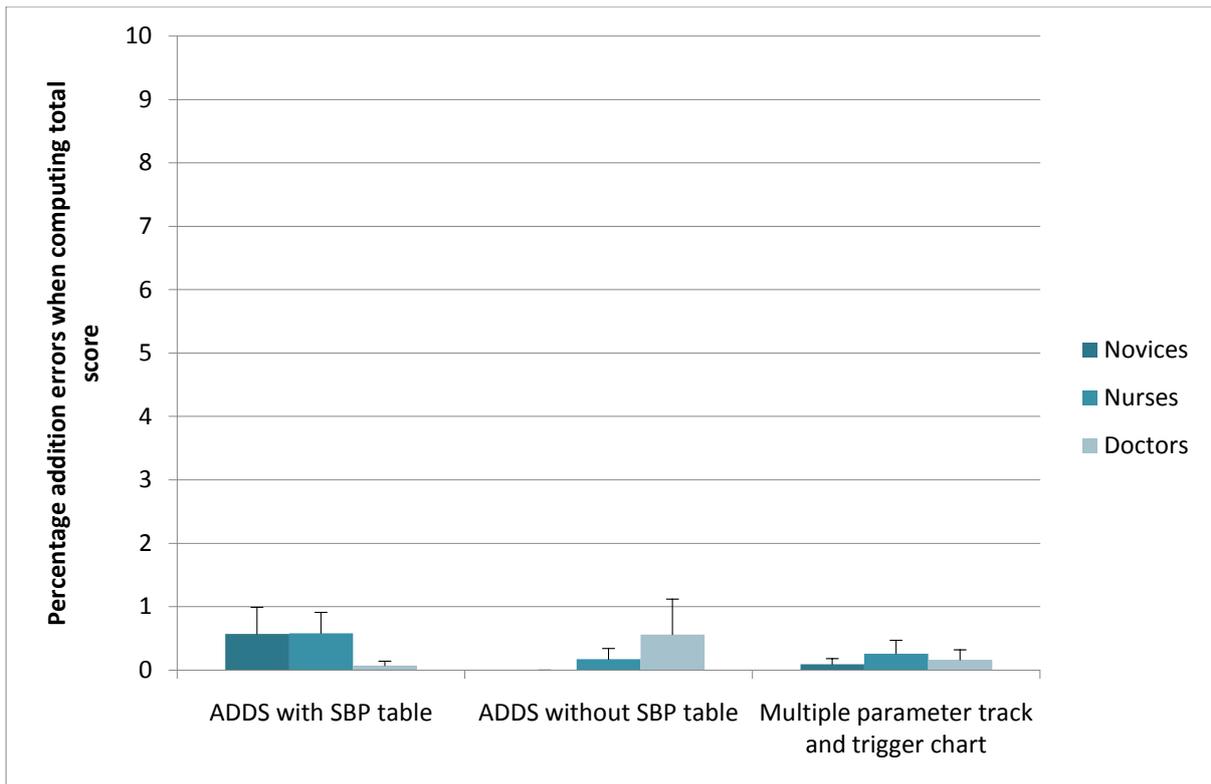


Figure 11: Percentage missing values anywhere in the scoring (error bars are standard errors of the mean). Note that the novices had no missing values for the ADDS without SBP table chart. Note, SBP = systolic blood pressure.

3.5 Participants' preferred chart

After the simulation, participants were asked which of the six charts they preferred. Preferences can be seen in Figure 9. Note that there was one nurse and one doctor who nominated both versions of the ADDS chart as their preferred chart and hence the ADDS with systolic blood pressure table and ADDS without systolic blood pressure table do not add up to the percent for the ADDS chart (either version) for these groups. The overall differences between charts were significant, $X^2(5) = 42.97$, $p < 0.001$ (removing individuals who nominated more than one chart to avoid independent problems).

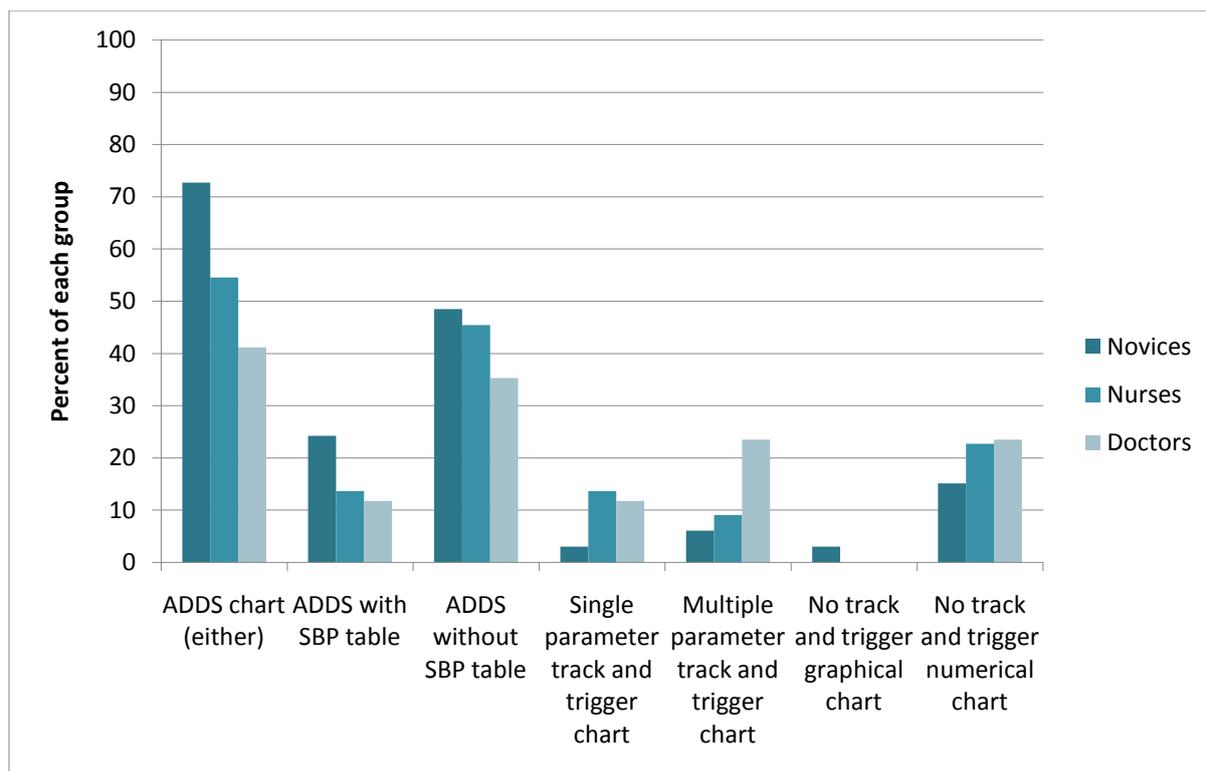


Figure 9: Percent of each group (novices, nurses, and doctors) who preferred each chart. Note, SBP = systolic blood pressure.

4. Discussion

Improving the recognition and management of patients who deteriorate whilst in hospital is a frequently cited priority for improving patient safety (1, 2). One way to improve the recognition and management of deteriorating patients is to improve the design of paper-based adult observation charts. The present study was designed to measure errors made when recording data onto charts under simulated hospital ward conditions.

De-identified patient data was to be recorded onto two versions of the new ADDS chart (designed to conform to human factors principles), two existing charts rated as “well designed”, one existing chart rated as being of “average design”, and one existing chart rated as “poorly designed”). Chart novices and health professionals were recruited as participants to record patient data onto six charts. Error rate was the main outcome of interest.

It was hypothesized that the simpler charts might yield fewer errors. However, we nonetheless predicted that, among the more complex charts, those designated as being better designed in the heuristic analysis would result in fewer errors in recording data.

The results of this experiment can be summarized as follows:

1. There were significant differences between the charts for the proportion of errors committed while recording data, indicating that chart design affected performance. To our knowledge, this

study is the first to provide empirical data that speaks to this issue. One key point to note about the error data is that the ranges are substantially smaller than those found in our previous experiment (comparing errors in detecting unstable vital signs across the same six charts). In the previous experiment, the worst chart was associated with 32.6% errors while the best chart resulted in 9.8% errors. In this experiment, the worst-performing chart yielded 2.3% errors (the multiple parameter track and trigger chart) while the best-performing chart yielded 0.2% errors (no track and trigger numerical chart). This indicates that, even though they were performing under non-ideal conditions (low light, auditory distractions, four hour session in the evening), participants made comparatively few errors when recording data into the charts. This is in contrast to the previous experiment in which participants were performing under ideal conditions (good light, no distractions, tested for one and a half hours during office hours) and yet had dramatically higher error rates in a task where chance performance was 50% (the current experiment did not have an equivalent chance level because the task of recording data correctly did not involve making a forced-choice judgement).

2. The rank order of charts in terms of error rates was completely different to the previous experiment, where the best chart in the current study (no track and trigger numerical chart) was the worst chart in the previous study and the ADDS charts were ranked in fourth and fifth place rather than first and second place. In terms of grouping charts by significant differences, the no track and trigger numerical chart was significantly better than all the other charts. This was presumably because the task of recording data simply involved the transposing of numbers directly from the simulated vital signs display to the chart. The no track and trigger graphical chart yielded more errors (presumably because three of the eight vital signs had to be converted into graphs) though this chart was still significantly better than the three charts involving a multiple parameter scoring system. The single parameter track and trigger chart was not significantly worse than the no track and trigger graphical chart. It was also not significantly better than the ADDS chart without systolic blood pressure table but it did perform significantly better than both the ADDS chart with systolic blood pressure table and the multiple parameter track and trigger chart (see non-parametric results given in the text of the results section). There were no significant differences between the three charts with multiple parameter track and trigger systems for recording vital sign data.

3. There were no differences in recording errors made by the novice group and the health professional group, but there was a collective difference between doctors and nurses across all charts (doctors committed fewer errors than nurses). However this difference did not reach significance for any one individual chart (note the substantial error bars in Figure 7, indicating a wide dispersion of scores).

4. For the three charts involving multiple parameter track and trigger systems (the two versions of the ADDS chart and the existing multiple parameter track and trigger chart), there was the opportunity for participants to make additional errors when scoring these systems. Again, the error rates in implementing the scoring systems were comparatively low relative to the errors from the previous experiment, ranging from 0.6% (ADDS chart without systolic blood pressure table) to 2.8% (existing multiple parameter track and trigger chart). The existing chart was significantly worse than both versions of the ADDS chart for errors introduced when using the scoring systems but the two versions of the ADDS chart did not differ from one another. These scoring errors were broken down into different types: errors made when scoring individual vital signs, errors made when adding up

the scores from individual vital signs to compute the overall score, and missing values. The ADDS charts were associated with significantly fewer errors than the existing multiple parameter chart, both for scoring individual vital signs and when adding up individual vital sign scores to compute the overall score. However, the percentage of these errors was very small relative to the errors found in the detecting abnormal vital signs experiment (for example, the doctors made no addition errors at all for any chart). Hence concerns that multiple parameter systems may be problematic because users will make a high number of errors when using them are not supported by the results of the present study.

5. All groups of participants appeared to prefer the ADDS chart (especially the ADDS chart without the systolic blood pressure table) to the other charts, despite this chart being associated with higher data-recording errors than some of the existing charts. This would seem to suggest that individuals were taking more account of the ease of interpreting the data (which, according to the previous experiment, the ADDS charts were the best at facilitating) rather than the ease of recording data. In terms of distinguishing between the two versions of the ADDS charts, it is worth noting that none of the performance measures from either of our experiments indicated any statistically reliable difference between the two. That is, we have no evidence that introducing the usual systolic blood pressure table reduces performance in either recording data or interpreting that data. Hence the decision as to whether to include the blood pressure table on the ADDS chart should be determined according to its clinical merit rather than its impact from a human factors perspective.

Overall, it appears that the simpler charts, especially those that involved data being recorded as numbers, resulted in the fewest errors. The more complex charts with multiple parameter track and trigger systems resulted in the highest number of errors, where there were also additional errors associated with the scoring of their track and trigger systems. These results yield a reverse order among the six charts compared with the previous experiment which looked at errors in recognising deterioration.

In order to decide which of the charts should be recommended as best practice overall, it was necessary to aggregate the findings from both studies. We have calculated aggregate errors using the following procedure:

(a) We calculated the **proportion of correct judgements** about whether an observation was normal or abnormal, assuming that the recorded data was completely accurate (using data taken from the previous experiment).

(b) We calculated the **proportion of the data that was correctly recorded** into each of the charts (from the results of the present experiment).

(c) We worked out the **proportion of the data that was both correctly judged and correctly recorded** by multiplying the outcomes of steps (a) and (b).

(d) We subtracted the outcome of step (c) from 1 to give an **overall error rate** for each chart.

(e) We converted the rate into a percentage by multiplying by 100.

The stages in this calculation can be viewed in Appendix K and the results of this procedure can be seen in Table 9. Also note that it is not possible to conduct statistical tests on these data because participants were not matched between the two studies.

Table 9: Overall errors for the six charts based on aggregating the findings from both the “detecting unstable vital signs” experiment and the present study, without adjusting for scoring errors on the multiple parameter track and trigger charts.

	Percent errors overall
ADDS with SBP table	11.49
ADDS without SBP table	13.24
Single parameter track and trigger chart	25.39
Multiple parameter track and trigger chart	25.91
No track and trigger graphical chart	31.60
No track and trigger numerical chart	32.70

Note. SBP = systolic blood pressure.

In order to attempt to judge the effect of scoring errors introduced via multiple parameter track and trigger systems (in the two ADDS charts and the existing multiple parameter track and trigger chart), we also performed a calculation where we derived the overall accuracy rate by multiplying the proportion of the data that was both correctly judged and correctly recorded ((a) x (b)) by the proportion of correct track and trigger system scores (see Appendix K for details). For charts with no multiple parameter track and trigger system, the correct scoring rate was entered as 1. The outcomes of this calculation can be viewed in Table 10.

Table 10: Overall errors for the six charts based on aggregating the findings from both the “detecting unstable vital signs” experiment and the present study, adjusting for scoring errors on the multiple parameter track and trigger charts.

	Percent errors overall
ADDS with SBP table	12.54
ADDS without SBP table	13.79
Single parameter track and trigger chart	25.39
Multiple parameter track and trigger chart	27.99
No track and trigger graphical chart	31.60
No track and trigger numerical chart	32.70

Note. SBP = systolic blood pressure.

In conclusion, it appears that, overall, the behavioural data still favour the two versions of the ADDS chart, which generated around half of the number of errors associated with the existing charts. It also indicates that despite the simpler charts (without track and trigger systems and using largely numerical data) generating fewer errors during data recording, they nonetheless remain the most problematic overall in terms of users making clinical decisions about the health of their patients.

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Appendix B: The ADDS chart without systolic blood pressure table

Note: Chart is printed at A3 size double-sided

DRAFT

DO NOT WRITE IN THE BINDING MARGIN

Date																										
Time																										
Respiratory Rate (breaths / min)	≥ 37																									≥ 37
	31-36																									31-36
	21-30																									21-30
O ₂ Flow Rate (L / min)	0-20																									0-20
	5-9																									5-9
	≤ 4																									≤ 4
O ₂ Saturation (%)	≥ 95																									≥ 95
	90-92																									90-92
	86-90																									86-90
Blood Pressure (mmHg)	With a 200																									With a 200
	100s																									100s
	180s																									180s
	170s																									170s
	160s																									160s
	150s																									150s
	140s																									140s
	130s																									130s
	120s																									120s
	110s																									110s
	100s																									100s
	90s																									90s
	80s																									80s
	70s																									70s
	60s																									60s
Heart Rate (beats / min)	With a 140																									With a 140
	130s																									130s
	120s																									120s
	110s																									110s
	100s																									100s
	90s																									90s
	80s																									80s
	70s																									70s
	60s																									60s
	50s																									50s
	40s																									40s
	30s																									30s
	20s																									20s
	10s																									10s
	Temperature (°C)	≥ 38.0																								
38-38.5																										38-38.5
36.1-37.9																										36.1-37.9
34.1-35																										34.1-35
4 Hour Urine Output (mL)	≥ 800																									≥ 800
	120-799																									120-799
	60-119																									60-119
	≤ 59																									≤ 59
Consciousness	Alert																									Alert
	Voice																									Voice
	Unresp.																									Unresp.
Increased pain																										
Respiratory Rate																										
O ₂ Flow Rate																										
O ₂ Saturation																										
Systolic BP																										
Heart Rate																										
Temperature																										
4 Hour Urine Output																										
Consciousness																										
TOTAL ADDS																										

Adult Deterioration Detection System (ADDS)

If any observation is in a shaded area, add up the Total ADDS Score and take action.

 Score 0
 Score 1
 Score 2
 Score 3
 MET call

Actions Required

<p>Total ADDS Score 1-3</p> <p><input type="checkbox"/> Record observations at least once every 4 hours</p> <p><input type="checkbox"/> Carry out appropriate interventions as prescribed</p> <p><input type="checkbox"/> Manage fever, pain or distress</p> <p><input type="checkbox"/> Review O₂ delivery</p> <p><input type="checkbox"/> Consider informing Team Leader</p>	<p>Total ADDS Score 4-5</p> <p><input type="checkbox"/> Ward doctor to review patient within 30 minutes</p> <p><input type="checkbox"/> Request review, and note on the back of this form</p> <p><input type="checkbox"/> Notify Team Leader</p> <p><input type="checkbox"/> Record observations at least once every 30 minutes</p> <p><input type="checkbox"/> If patient must leave ward area, Nurse must accompany patient</p>
<p>Total ADDS Score 6-7</p> <p><input type="checkbox"/> Registrar to review patient within 30 minutes</p> <p><input type="checkbox"/> Request review, and note on the back of this form</p> <p><input type="checkbox"/> Registrar to ensure consultant is notified</p> <p><input type="checkbox"/> Ward doctor to attend</p> <p><input type="checkbox"/> If patient must leave ward area, Intern and Nurse must accompany patient</p>	<p>Total ADDS Score ≥ 8</p> <p><input type="checkbox"/> Consider MET call</p> <p><input type="checkbox"/> Registrar to review patient within 10 minutes</p> <p><input type="checkbox"/> Request review, and note on the back of this form</p> <p><input type="checkbox"/> Registrar to ensure Consultant is notified</p> <p><input type="checkbox"/> If patient must leave ward area, Registrar and Nurse must accompany patient</p>

Medical Emergency Team (MET) call if:

- Any observation is in a purple area
- Airway threat
- Respiratory or cardiac arrest
- New drop in O₂ saturation < 90%
- Sudden fall in level of consciousness
- Seizure
- You are seriously worried about the patient but they do not fit the above criteria

DRAFT

DO NOT WRITE IN THE BINDING MARGIN

Adult Deterioration Detection System (ADDS) Chart

Facility: _____ of _____

Chart number: _____ of _____

Family name: _____

Given name: _____

Date of birth: _____ Sex: M F

Observations

- You should record appropriate observations:
 - On admission
 - At a frequency appropriate for the patient's clinical state
 - Whenever you are concerned about the patient.
- For each vital sign (except blood pressure and increased pain), place a dot (•) in the centre of the box which includes the current observation in its range of values. Then draw a line between this dot and the previous dot to create a graph (unless this is the first observation). For blood pressure and increased pain, use the symbols indicated on the chart.
- Whenever an observation falls within a shaded area, you must enter the ADDS Score for that vital sign in the appropriate row of the ADDS Scores table.
- Every time that observations are recorded, you must enter a Total ADDS Score (even if 0).

Modifications

If abnormal observations are to be tolerated for the patient's clinical condition, write the acceptable ranges (where the ADDS Score will be 0) below.

Respiratory Rate	to		Doctor's name (please print)
O ₂ Flow Rate	to		Designation
O ₂ Saturation	to		Signature
Systolic BP	to		
Heart Rate	to		
Temperature	to		Date: / / Time: :
4 Hour Urine Output	to		
Consciousness	to		

Interventions

1
2
3
4
5
6
7
8

DRAFT

DO NOT WRITE IN THE BINDING MARGIN

Clinical Reviews

Review requested Date: / / Time: : : Ward doctor Registrar MET

Reason: ADDS Other Specify: _____

Review undertaken Date: / / Time: : :

	✓	Not examined	Normal	Abnormal	If abnormal, give details
Airway					
Breathing					
Circulation					
Neurology					
Skin					
ENT					
Bones / Joints					

Management: Management changed → Specify: _____

No change, observe

Doctor's name (please print): _____ Designation: _____ Signature: _____

Review requested Date: / / Time: : : Ward doctor Registrar MET

Reason: ADDS Other Specify: _____

Review undertaken Date: / / Time: : :

	✓	Not examined	Normal	Abnormal	If abnormal, give details
Airway					
Breathing					
Circulation					
Neurology					
Skin					
ENT					
Bones / Joints					

Management: Management changed → Specify: _____

No change, observe

Doctor's name (please print): _____ Designation: _____ Signature: _____

Appendix C: Single parameter track and trigger chart

Note: Chart is printed at A3 size double-sided and has been de-identified. Note that the chart used in this study did not have modified track and trigger cut-offs (unlike its counterpart in the “detecting abnormal vital signs” study).

ADULT GENERAL OBSERVATION CHART

Facility: _____

FAMILY NAME: _____ MRN: _____
 GIVEN NAME: _____ MALE FEMALE
 D.O.B. _____ / _____ / _____ M.O.
 ADDRESS: _____
 LOCATION: _____

Altered Calling Criteria COMPLETE ALL DETAILS OR AFFIX PATIENT LABEL HERE

AIRWAY/BREATHING	Date			
	Time			
	Respiratory Rate			
	SpO ₂			
	O ₂ Sat			
	CIRCULATION	Blood Pressure (mmHg)		
		Heart Rate		
		URINARY	Urine Output	
			Urine Color	
			Urine Specific Gravity	
DISABILITY	Level of Consciousness			
	Neurological			

Legend: Rapid Response Clinical Review

Page 2 of 4

ADULT GENERAL OBSERVATION CHART

Facility: _____

FAMILY NAME: _____ MRN: _____
 GIVEN NAME: _____ MALE FEMALE
 D.O.B. _____ / _____ / _____ M.O.
 ADDRESS: _____
 LOCATION: _____

COMPLETE ALL DETAILS OR AFFIX PATIENT LABEL HERE

Date: _____
 Time: _____

TEMPERATURE (T _{CO}) + (If 36.0°C Consider Blood Culture - Check Unit Policy)	>40	
	40	
	39	
	38	
	37	
	36	
	35	
	34	
	<34	
	PAIN SCORE	
(No pain) 0		
5		
10 (Worst)		

Date: _____
 Time: _____

Scale: _____

Date: _____
 Time: _____
 BGL: _____

Date: _____
 Time: _____

Weight: _____
 Daily

Date: _____
 Time: _____

Fluid Summary

Output	Total
Urine	Total

BALANCE: _____

Date: _____
 Time: _____

pH: _____
 Lactate: _____
 Blood Urea Nitrogen: _____
 Creatinine: _____
 Cholesterol: _____
 Urea Nitrogen: _____
 Protein: _____
 Glucose: _____

Page 3 of 4

ADULT GENERAL OBSERVATION CHART

Facility: _____

FAMILY NAME: _____ MRN: _____
 GIVEN NAME: _____ MALE FEMALE
 D.O.B. _____ / _____ / _____ M.O.
 ADDRESS: _____
 LOCATION: _____

COMPLETE ALL DETAILS OR AFFIX PATIENT LABEL HERE

OTHER CHARTS IN USE

Neuro Insulin Infusion Alcohol Withdrawal
 Fluid Balance Pain / Epidural / Patient Control Analgesia Other _____
 Anticoagulant Neurovascular Other _____

VARIATIONS TO FREQUENCY OF OBSERVATIONS

DATE: _____
 Frequency Required: _____
 Medical or Rapid Response Officer Name: _____
 Signature: _____

ALTERATIONS TO CALLING CRITERIA (MUST BE REVIEWED AT LEAST EVERY 72 HOURS)
 ANY ALTERATIONS MUST BE CONFIRMED BY CONSULTANT

DATE: _____
 Respiratory Rate: _____
 Systolic Blood Pressure: _____
 SpO₂: _____
 Heart Rate: _____
 Other: _____

Consultant Medical Officer Name: _____
 Signature: _____

INTERVENTIONS

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Page 1 of 4

ADULT GENERAL OBSERVATION CHART

Facility: _____

FAMILY NAME: _____ MRN: _____
 GIVEN NAME: _____ MALE FEMALE
 D.O.B. _____ / _____ / _____ M.O.
 ADDRESS: _____
 LOCATION: _____

COMPLETE ALL DETAILS OR AFFIX PATIENT LABEL HERE

OTHER CHARTS IN USE

Neuro Insulin Infusion Alcohol Withdrawal
 Fluid Balance Pain / Epidural / Patient Control Analgesia Other _____
 Anticoagulant Neurovascular Other _____

VARIATIONS TO FREQUENCY OF OBSERVATIONS

DATE: _____
 Frequency Required: _____
 Medical or Rapid Response Officer Name: _____
 Signature: _____

ALTERATIONS TO CALLING CRITERIA (MUST BE REVIEWED AT LEAST EVERY 72 HOURS)
 ANY ALTERATIONS MUST BE CONFIRMED BY CONSULTANT

DATE: _____
 Respiratory Rate: _____
 Systolic Blood Pressure: _____
 SpO₂: _____
 Heart Rate: _____
 Other: _____

Consultant Medical Officer Name: _____
 Signature: _____

INTERVENTIONS

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Page 1 of 4

THESE INSTRUCTIONS EXPLAIN WHEN TO MAKE A CLINICAL REVIEW OR RAPID RESPONSE CALL. YOUR LOCAL ESCALATION PROTOCOL WILL EXPLAIN HOW TO MAKE A CALL.

Clinical Review Criteria

- Post peripheral circulation
- Excess or increasing blood loss
- Respiratory Rate 5 - 8 or 21 - 30 breaths per minute
- SpO₂ 90 - 92% and/or increase in oxygen (O₂) requirement
- Systolic Blood Pressure 90 - 109 or 160 - 200mmHg
- Heart Rate 40-49 or 100-140 beats per minute
- Decline in Level of Consciousness from "Alert" to "Vague" in the AVPU or new onset of confusion
- Temperature $\leq 36.0^{\circ}\text{C}$ or $\geq 38.0^{\circ}\text{C}$
- Anuria, failure to void in 24 hours or urine output $<20\text{ml}$ over 8 hours
- Greater than expected fluid loss from a drain or polyuria ($>200\text{ml/hr}$ for 2 hours in the absence of diuretics)
- Blood Glucose Level <4 mmol/L
- New, increasing or uncontrolled pain (including chest pain)

IF A PATIENT HAS ANY ONE (1) OR MORE CLINICAL REVIEW CRITERIA PRESENT, YOU MUST CONSULT PROMPTLY WITH THE NURSE IN CHARGE AND ASSESS WHETHER A CLINICAL REVIEW IS NEEDED (REFER TO YOUR LOCAL ESCALATION PROTOCOL) AND:

- You MUST initiate appropriate clinical care
- Repeat and record observations as indicated by the patient's condition, but at least within 30 minutes
- If you called for a Clinical Review and it has not been attended within 30 minutes, you MUST ACTIVATE YOUR LOCAL RAPID RESPONSE
- If the patient's observations enter the RED Zone while you are waiting for a Clinical Review, you MUST ACTIVATE YOUR LOCAL RAPID RESPONSE (see below)
- You may call for a Clinical Review at any time if worried about a patient or are unsure whether to call.

You should consider:

- Whether abnormal observations reflect deterioration in your patient.
- What is usual for your patient or if there are altered calling criteria (see front of chart)
- Whether there is an adverse trend in observations

Rapid Response Criteria

- ALL respiratory and cardiac arrests
- Anyway obstruction or stridor
- Seizures
- Deterioration not reversed within 1 hour of clinical review
- Patient deteriorates further, before or during clinical review
- Arterial Blood Gas: P_{O₂} <60 , or P_{O₂} >80 , or pH <7.2 , or BE <-5
- Venous Blood Gas P_{O₂} >65 or pH <7.2
- Respiratory Rate <5 or >30 breaths per minute
- SpO₂ $<90\%$ and/or increase in oxygen (O₂) requirement
- Systolic Blood Pressure <90 or $\geq 200\text{mmHg}$
- Heart Rate <40 or >140 beats per minute
- Sudden decrease in Level Of Consciousness (GCS ≥ 2 points), only responds to central pain or unresponsive
- Serious concern by any staff member

IF A PATIENT HAS ANY ONE (1) RAPID RESPONSE CRITERION PRESENT, CALL FOR A RAPID RESPONSE (REFER TO YOUR LOCAL ESCALATION PROTOCOL) AND:

- You MUST initiate appropriate clinical care
- Inform the Nurse in Charge
- Repeat observations as indicated by the patient's condition

CHECK THE CLINICAL RECORD FOR ADVANCE CARE DIRECTIVES OR ALTERATIONS TO CALLING CRITERIA WHICH MAY AFFECT WHETHER A CLINICAL REVIEW OR RAPID RESPONSE CALL IS INDICATED

DOCUMENTATION

- Write interventions on the front of the chart under 'Interventions'.
- Write treatment, escalation process, and outcome in the clinical record
- Write date, signature and designation with each entry

Page 4 of 4

Appendix D: Multiple parameter track and trigger chart

Note: Chart is printed at A4 size double-sided and has been de-identified

Modified Early Warning Scores		0	1	2	3	Observation chart number:
Date						
Time						
Resp Rate	≥ 36					
	31 – 35					
MET RR	21 – 30					
	< 5 or > 36					
RR Score						
SpO ₂	Oxygen mode (L/min)					
	≥ 50					
	90 – 92					
	85 – 89					
SpO ₂ Score						
Temp (°C)	≥ 39.6					
	38.6 – 39.5					
	38 – 38.5					
	37 – 37.9					
	36.1 – 36.9					
	34.1 – 35					
Temp Score						
Blood Pressure & Heart Rate ()	200					
	190					
	180					
	170					
	160					
	150					
	140					
	130					
	120					
	110					
	100					
	40					
Score RR						
Score BP (see back)						
Sedation Score	0					
	1					
	2					
	3					
	4					
Sedation Score						
Urine for AAs	> 500					
	150 – 500					
	80 – 119					
Urine Score						
TOTAL MEWS						
Pain						
Bowels						
Initial						

Date																																																																																																																																																																																																														
Time																																																																																																																																																																																																														
Weight																																																																																																																																																																																																														
DY/PE Risk																																																																																																																																																																																																														
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Urinalysis																																																																																																																																																																																																														
Date				Height:		Weight on Admission:		Other obs charts in use: <input type="checkbox"/> PCA <input type="checkbox"/> Epikural <input type="checkbox"/> Neurological <input type="checkbox"/> Blood transfusion <input type="checkbox"/> Underwater seal <input type="checkbox"/> Neurovascular <input type="checkbox"/> Peak flow <input type="checkbox"/> Alcohol withdrawal <input type="checkbox"/> Fluid balance <input type="checkbox"/> Bladder irrigation <input type="checkbox"/> Post angiogram <input type="checkbox"/> Post procedural <input type="checkbox"/> Stool chart <input type="checkbox"/> Blood glucose																																																																																																																																																																																																						
Time				BMI		Pain Score																																																																																																																																																																																																								
Leucocytes				Sedation Score: 0 = awake & alert 1 = normally asleep, responds to stimuli 2 = mild, occasionally drowsy, easy to rouse 3 = moderate, frequently drowsy easy to rouse but unable to maintain wakeful state 4 = severe, somnolent, difficult to rouse		No pain – 0 Worst – 10																																																																																																																																																																																																								
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Appendix G: Questionnaire for novices

Questions About Your Background

All responses are completely anonymous. Please answer the following questions as honestly and accurately as possible. There are no right or wrong answers.

1. Your sex:

- Female
- Male

2. Your age:

_____ years

3. Are you colour-blind?

- Yes
- No

If you answered 'Yes':

4. What type of colour-blindness do you have? (E.g. "red-green")

5. Does your colour-blindness impact on your work or studies?

- Yes
- No

6. Do you wear glasses or contact lenses in order to read?

- Yes
- No

7. Was English your first language?

- Yes
- No

8. Did you complete the majority your professional training or schooling in English?

- Yes
- No

9. Please indicate the description-step that better reflects the psycho-physical state you have experienced in the last ten minutes:

- = extremely alert
- = very alert
- = alert
- = rather alert
- = neither alert nor sleepy
- = some signs of sleepiness
- = sleepy, no effort to stay awake
- = sleepy, some effort to stay awake
- = very sleepy, great effort to keep awake, fighting sleep

10. Have you ever worked as a health professional (e.g. nurse)?

- Yes
- No

If you answered '**Yes**', please describe your work as a health professional:

11. Have you ever used a Hospital Observation Chart before?

- Yes
- No

If you answered '**Yes**', please describe your experience with Charts:

Appendix H: Questionnaire for health professionals

Questions About Your Background

All responses are completely anonymous. Please answer the following questions as honestly and accurately as possible. There are no right or wrong answers.

1. What is your occupation?
 - Nurse
 - Doctor
 - Other health professional (please specify: _____)

2. Which of the following best describes your **nursing** role?
 - Enrolled Nurse
 - Nursing Assistant
 - Registered Nurse
 - Clinical Nurse
 - Nurse Unit Manager
 - Clinical Nurse Consultant
 - Nurse Educator
 - Nursing Director
 - Nurse Practitioner
 - Other (please specify: _____)

3. Which of the following best describes your **medical** role?
 - Post-graduate year 1 (Intern)
 - Post-graduate year 2 and not in an accredited training program
 - Post-graduate year 3 and not in an accredited training program
 - Post-graduate year 4+ and not in an accredited training program
 - Post-graduate and in an accredited training program
 - Hospitalist
 - Career Medical Officer
 - Senior Medical Officer
 - Visiting Medical Officer
 - Staff Specialist
 - Senior Staff Specialist
 - Other (please specify: _____)

4. How many years have you been registered?
_____ years

5. What is the postcode of your institution or place of work? _____

6. At your institution, where do you spend the greatest proportion of your time working?

- Ward
- Emergency
- ICU
- Theatre
- Outpatient Clinic
- Management/administration
- Other (please specify:

_____)

7. Your sex:

- Female
- Male

8. Your age:

_____ years

9. Are you colour-blind?

- Yes
- No

If you answered 'Yes':

a. What type of colour-blindness do you have? (E.g. "red-green")

b. Does your colour-blindness impact on your work?

- Yes
- No

10. Do you wear glasses or contact lenses in order to read?

- Yes
- No

11. Was English your first language?

- Yes
- No

12. Did you complete the majority your professional training (e.g. BNurs, MB BS) in English?

- Yes
- No

13. Please indicate the description-step that better reflects the psycho-physical state you have experienced in the last ten minutes:

- = extremely alert
- = very alert
- = alert
- = rather alert
- = neither alert nor sleepy
- = some signs of sleepiness
- = sleepy, no effort to stay awake
- = sleepy, some effort to stay awake
- = very sleepy, great effort to keep awake, fighting sleep

The next few questions are about your current use of Observation Charts.

14. Do you **use** Observation Charts as part of your current role?

- Yes
- No

15. How frequently do you **use** Observation Charts?

- More than once a day
- Once a day
- More than once a week, but less than once a day
- Once a week
- More than once a month, but less than once a week
- Once a month
- Less than once a month

16. Do you **record information** in Observation Charts as part of your current role?

- Yes
- No

17. How frequently do you **record information** in Observation Charts?

- More than once a day
- Once a day
- More than once a week, but less than once a day
- Once a week
- More than once a month, but less than once a week
- Once a month
- Less than once a month

18. What **training** have you received in the use of Observation Charts? (tick all that apply)

- None
- Read the instructions
- Informal (e.g. by co-worker)
- Formal (e.g. in-service or workshop)
- Other (please specify:

_____)

Appendix I: Post-simulation questionnaire for both groups

Post-Simulation Questions

1. Are you:
 - Right handed
 - Left handed
2. Have you previously used a chart that was very similar to any of the Observation Charts that were presented in the study?
 - Yes
 - No

If you answered 'Yes':

Which of the Observation Charts was/were similar to a chart that you have previously used **in terms of the superficial appearance (e.g. colours)?** (You may tick more than one option)

- ADDS Chart with the blood pressure table
- ADDS Chart without the blood pressure table
- [chart name removed]
- [chart name removed]
- [chart name removed]
- [chart name removed]

Which of the Observation Charts was/were similar to a chart that you have previously used **in terms of the track and trigger system used (or lack of one)?** (You may tick more than one option)

- ADDS Chart with the blood pressure table
- ADDS Chart without the blood pressure table
- [chart name removed]
- [chart name removed]
- [chart name removed]
- [chart name removed]

Which of the Observation Charts was/were similar to a chart that you have previously used **in terms of how the vital signs were displayed?** (You may tick more than one option)

- ADDS Chart with the blood pressure table
- ADDS Chart without the blood pressure table
- [chart name removed]
- [chart name removed]
- [chart name removed]
- [chart name removed]

3. Please indicate the description-step that better reflects the psycho-physical state you have experienced in the last ten minutes:

- = extremely alert
- = very alert
- = alert
- = rather alert
- = neither alert nor sleepy
- = some signs of sleepiness
- = sleepy, no effort to stay awake
- = sleepy, some effort to stay awake
- = very sleepy, great effort to keep awake, fighting sleep

4. Which chart did you like using the best?

- ADDS Chart with the blood pressure table
- ADDS Chart without the blood pressure table
- [chart name removed]
- [chart name removed]
- [chart name removed]
- [chart name removed]

Why did you like using this chart?

5. Do you have any comments about the other charts?

6. Do you have any comments about the research in general?

Appendix J: Testing manual for researchers (both groups)

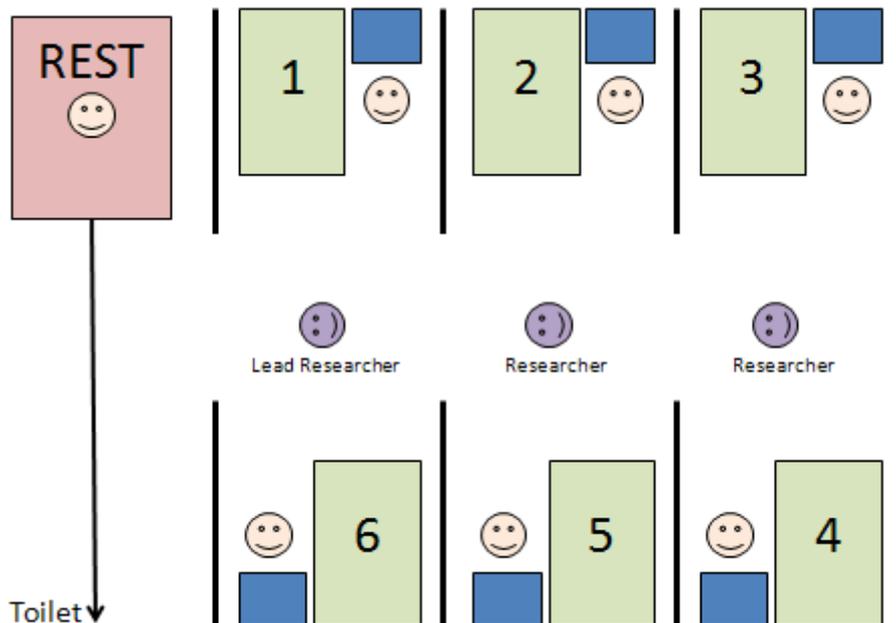
Simulation Study Instructions for RAs

Very Important!

If you are running late or cannot attend a testing session for whatever reason, let Megan know as soon as possible on [phone number removed].

Before Arriving at the Hospital (MEGAN)

- Ensure Simulation Ward is booked. Contact [name removed] to arrange bookings.
- Ensure there is enough money to pay all participants



Pre-Participant setup (MEGAN & RAs)

- Getting there
 - Park in the SDC Loading Dock unless you've been told otherwise
 - Call Megan to let you into the building
- Ward
 - Adjust lighting to determined level
- Signs
 - Directions from Reception to Ward
 - Directions from Ward to Toilet
 - Make sure signs on door of ward are set to "Simulation in Progress"
 - Bed number & patient name

- Set-up flipchart (that displays the time-point of the experiment) at the end of the Ward. RA's need to identify each time-point and verify that it is the time-point displayed on screen. The Lead RA will change the flipchart to the next time-point
- Speakers and cables:
 - Can be found in cupboards in each patient bay
 - Move the beds and beside cabinets forward before attempting to install speakers.
 - For each pair of speakers: Volume & tone on maximum
 - Set –up as follows:
Bay 1: speaker with knobs on **right**.
Bay 2: speaker with knobs on **left**.
Bay 3: speaker with knobs on **right**.
Bay 4: speaker with knobs on **left**.
Bay 5: speaker with knobs on **right**.
Bay 6: speaker with knobs on **left**.
 - Within each pair of speakers:
The **left** speaker should be as far left as possible (i.e., abutting the curtain, if possible).
The **right** speaker should be approximately 5cm to the right of the beside cabinet. (Use the most appropriate powerpoint to ensure the required distance between the 2 speakers).
 - Ensure that the cable that runs across the room is taped down along its entire length.
- Other Audio equipment
 - Set up next to Bay 3.
 - Turn on powerboard for Zoom & Presonus
 - Audio player (looks like a mike), named “Zoom”
 - Volume = 36
 - Presonus (headphone amp)
 - Input A = max
 - Input B = 0
 - Talkback level = 0
 - For channels 1 – 6:
 - Mix = A
 - Ext in = 0
 - Level = max
 - **NO** mute lights on
 - **NO** mono lights on
 - Channels 1 - 3 = opposite side of room
 - Channels 4 – 6 = this side of room

- Test the system to verify that all speaker pairs are working before putting the beds and cabinets back to their original positions.
- Patient Bays
 - Arrange 6 beds according to figure above
 - Draw curtains
 - End of bed railings on
 - All beds fully reclined
 - Dummy head in each bed, and pillows to simulate a body (in cupboard 9A)
 - Stool
 - Bedside table to be touching side of the bed
 - 1 tissue box
 - 1 blue folder with 6 laminated practice charts (put on bed)
 - 1 practice pen (the felt tip ones)
 - 1 clock
 - 1 bin
- Rest station
 - 1 tissue box
 - 1 blue folder with 6 laminated practice charts
 - 1 practice pen (the felt tip ones)
 - 1 clock
 - 1 bin
- Laptops
 - 6 in patient bays for practice & experiment, 1 in rest station for practice) on each of the bedside tables
 - Powerpacks connected
 - Plugged into mains
 - Mains switch is on
 - Green dot on left mouse button
 - Attach the headphones to each laptop (ensure the volume is at an appropriate level)
 - Media set up for each participant to watch instructions
 - Click **Media** on the desktop
 - Click **Media** shortcut (looks like filmstrip) in that folder
 - Click **Run Experiment**
 - The 'Loading...' window appears, click '**Browse**'. Under 'Data', select the correct participant number and click '**Open**'
 - Click '**Load**' in the 'Loading...' window
 - The 'Subject identifier' window appears, enter the participant's number e.g. "01"
 - The first screen of the Instructions presentation will appear

Participants arrive (MEGAN & RAs)

- Write pt's 1st name on a label
- Usher pt to correct patient bay
 - Consult the randomisation sheet, i.e.:
 - Nurse 1-Bed1
 - Nurse 2-Bed2
 - Nurse 3-Bed3
 - Nurse 4-Bed4
 - Nurse 5-Bed 5
 - Nurse 6-Bed 6
 - Nurse 7-Rest station
- Information & Consent form
- Background questionnaire
- Headphones on, start instructions
- When the time for the beginning of the session has passed, an RA takes the randomisation sheet and crosses of the names of any pts who have not arrived
- When pts finish instructions, ask if want to go to the toilet/have a drink/snack before simulation begins
 - If someone finishes way ahead of other pts, give them a magazine
 - Remove green dot
 - Remove practice folders
 - Remove felt tip pens
 - Remove headphones
 - Each pt should be given a pen on a lanyard
- Chart Roulette
 - Start the "Chart Roulette" program
 - Open the file that corresponds to the correct session
 - Enter the session number
 - Enter the correct bed number
 - Enter the names of the nurses into the "Chart Roulette" program
 - Nurse 1 = the nurse at bed 1 etc (i.e. same order for each laptop)

Participant-Practice setup (MEGAN & RAs)

This list of things can be done while participants are watching the instructions if necessary (n.b. 1 RA should be free to help pts/answer questions):

- Rest station
 - Magazines
 - Water
 - Juice

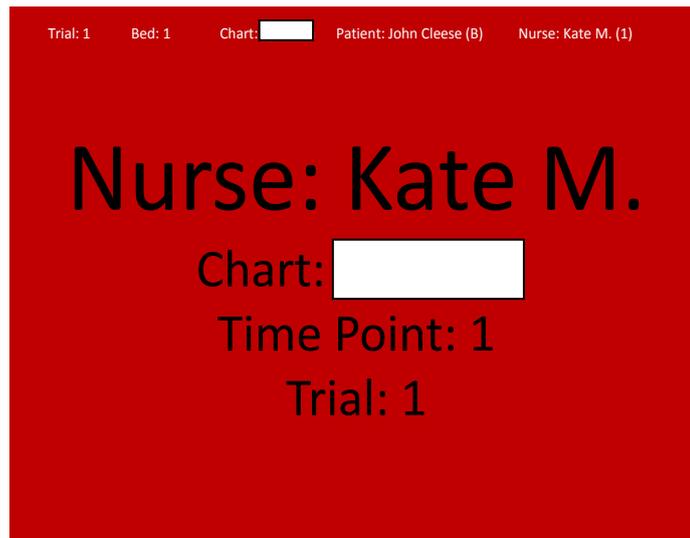
- Biscuits, sultanas, Freddos
- Paper plates
- Serviettes
- Some labels & felt tip pen (e.g. if pts want to label a waterbottle)
- Arrange charts & folders for each bed
 - Folder holder on end of bed
 - Correct Clinical Concern Rating booklet for bed number in each folder holder
 - Bed 1 = black, Bed 2 = red, Bed 3 = green, Bed 4 = black, Bed 5 = red, Bed 6 = green
 - Nurse's names & number & bed on labels on each folder & their chart inside
 - Ballot box on each bed

SIMULATION (RAs)

- During testing, each RA is responsible for a maximum of two beds (usually 1&6, 2&5 or 3&4), and therefore two particular pts during each trial
- Pts will get their folder from the holder, watch that they pick up the right one **& that they don't open it before the trial begins**
- Lead RA needs a stopwatch & whistle

Trial 1

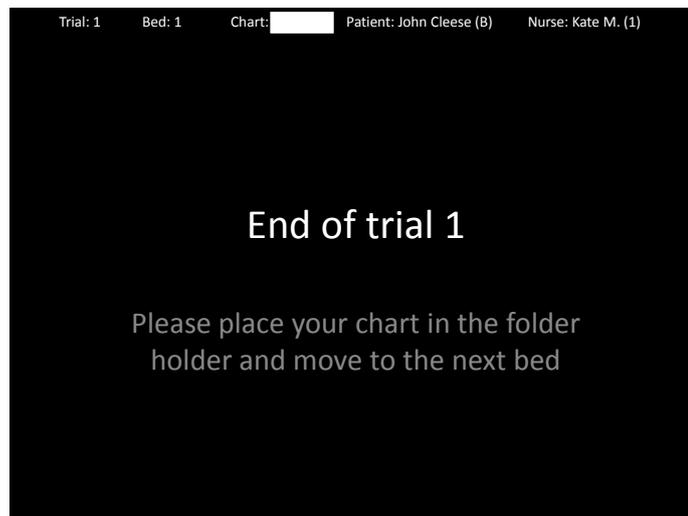
- Program prompts RA to enter Trial number from 1-63 (i.e. 1)
- Start-up screen is displayed. This will show once each session. RA verifies bed number, session number, patient name and letter, and the 6 nurse's names and numbers.
 - **We must be sure all this information is correct, spend as much time as you need to double & triple-check this screen**
- Once verified, RA presses F1-ENTER to progress to the next screen.
- A coloured screen that displays a running header (including trial number, bed number, chart type, patient name and letter) and in large font the nurses names, chart name, timepoint and trial number.



- Lead RA looks around the room at all of the screens to verify that all of the screens are on the same time point. Seven colours will rotate through the trials. For example:
 - Trial 1-Red
 - Trial 2-Green
 - Trial 3-Purple
 - Trial 4-Yellow
 - Trial 5-Blue
 - Trial 6-Orange
 - Trial 7-Pink.
 - Then when the nurses return to their original bed, the colour sequence begins again).
- Lead RA warns the nurses that a trial is about to start, so that they have their fingers ready to press the space bar, ask anyone who's not ready to say so.
- The senior RA shouts "Ready, set, go!" & starts timing
 - On "Go!", pts press the spacebar to begin the trial
 - The screen that displays the vital signs will appear for 2 minutes. The progress bar displayed at the bottom of the screen will let the pts monitor their time.

Trial: 2	Bed: 1	Chart: []	Patient: John Cleese (B)	Nurse: Emma T. (1)
T	37.7	Sedation	A	
P	94	Pain	0	
R	18			
SBP	126	DBP	68	
SPO2/O2	95			

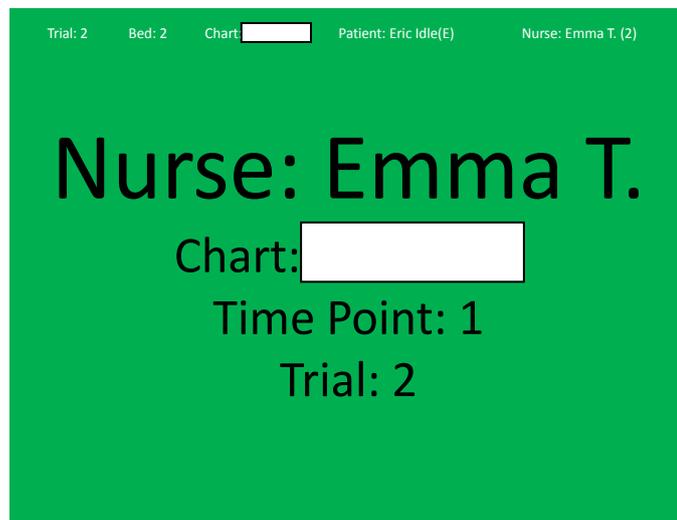
- At the end of 2 minutes, Lead RA blows the whistle
 - Pts should immediately close their folder. Simultaneously (give or take a few milliseconds), each computer will automatically display an “End of Trial” screen.
- Pts will return their folder to the holder
- RA gives pt the **top sheet** from the Clinical Concern Rating booklet
 - Pt fills it out, puts in ballot box
- After pts have made their rating, pts moves to next bed



Trial 2

- Lead RA changes the flipchart to next page (Trial 2)
- Pts move to their 2nd bed, i.e.:
 - Nurse 1-Bed 2
 - Nurse 2-Bed 3

- Nurse 3-Bed 4
- Nurse 4-Bed 5
- Nurse 5-Bed 6
- Nurse 6-Rest Station
- Nurse 7-Bed 1
- Pts get their folder
- A coloured screen that displays a running header (including trial number, bed number, chart type, patient name and letter) and in large font the nurses names, chart name, timepoint and trial number. The colour will correspond to the aforementioned trial number (i.e. Trial 2-Green)



- Lead RA warns the nurses that a trial is about to start, so that they have their fingers ready to press the space bar, ask anyone who's not ready to say so....

This procedure needs to be followed for 63 trials in total

Post-Simulation (MEGAN & RAs)

- At the end of the 63rd trial, inform nurses that they have completed their last trial
- Post-experiment questionnaires
- Debrief sheets
- **ASK FOR THE PEN ON THE LANYARD TO BE GIVEN BACK**
- Megan pays each pt & gets them to sign "Payments to Research Participants" form.
- Thank the pts and assist them in finding their way out of the building
 - Offer to escort people to their cars

Post-Participants (MEGAN & RAs)

- Collect **each pt's** data put in a plastic sleeve with a cover page stating at a minimum:
 - Session number (or the date)
 - Nurse number in the session
 - Data include:
 - Background questionnaire
 - 6 charts
 - Post-experiment questionnaire
- **Only then** remove all labels from the folders
- Take down signs
- Shut down laptops & leave in Marcus's office
- Identify any equipment that Megan needs to replace, e.g. food/drinks, paper forms
- Pack away all equipment
 - **Roll up & put loose cable ends into nearest cupboard or the box**

Appendix K: Calculations to determine overall errors associated with each chart

The following table illustrates the calculation steps to determining the overall percentage error by chart, **without including errors introduced in the charts using multiple parameter track and trigger systems**. The calculation steps are described in the column headings, moving from left to right.

	(a) Detecting abnormal vital signs: proportion of correct decisions	(b) Recording data: proportion of correctly entered data	(c) Proportion correct overall (A x B)	(d) Error rate overall (1 - C)	(e) Percentage errors overall (D x 100)
ADDS with SBP table	0.9017	0.9816	0.8851	0.1149	11.49
ADDS without SBP table	0.8834	0.9821	0.8676	0.1324	13.24
Single parameter track and trigger chart	0.7542	0.9892	0.7461	0.2539	25.39
Multiple parameter track and trigger chart	0.7584	0.9769	0.7409	0.2591	25.91
No track and trigger graphical chart	0.6882	0.9938	0.6840	0.3160	31.60
No track and trigger numerical chart	0.6742	0.9983	0.6730	0.3270	32.70

Note. SBP = systolic blood pressure.

The following table illustrates the calculation steps to determining the overall percentage error by chart, **including errors introduced in the charts using multiple parameter track and trigger systems**. The calculation steps are described in the column headings, moving from left to right.

	(a) Detecting abnormal vital signs: proportion of correct decisions	(b) Recording data: proportion of correctly entered data	(c) Scoring of multiple parameter track and trigger systems: proportion correct	(d) Proportion correct overall (a x b x c)	(e) Error rate overall (1 - d)	F. Percentage errors overall (e x 100)
ADDS with SBP table	0.9017	0.9816	0.9881	0.8746	0.1254	12.54
ADDS without SBP table	0.8834	0.9821	0.9936	0.8621	0.1379	13.79
Single parameter track and trigger chart	0.7542	0.9892	1.0000	0.7461	0.2539	25.39
Multiple parameter track and trigger chart	0.7584	0.9769	0.9719	0.7201	0.2799	27.99
No track and trigger graphical chart	0.6882	0.9938	1.0000	0.6840	0.3160	31.60
No track and trigger numerical chart	0.6742	0.9983	1.0000	0.6730	0.3270	32.70

Note. SBP = systolic blood pressure.