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Laboratory Investigation

LABORATORY INVESTIGATION

Using an animated patient avatar to improve perception of vital sign information by anaesthesia professionals

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Abstract

Background: Maintaining situation awareness of monitored patients can be challenging because care providers must continually read and integrate multiple waveforms and numerical vital sign values into a mental model of the patient's situation. We developed and evaluated a technology designed to improve perception of vital sign information by presenting patient status as an animated patient avatar.

Methods: After step-wise improvement of the avatar, anaesthesia professionals from two hospitals participated in a comparative study of conventional monitoring. Participants observed identical monitoring scenarios via the two technologies for brief time intervals and afterwards recalled patient status.

Results: Overall, 150 anaesthesia professionals participated in the validation process and 32 participated in the comparative study, completing 128 scenarios, which allowed for 64 direct comparisons. The avatar's inter-rater reliability was high, with Fleiss' kappa of 0.98 (95% confidence interval 0.96–0.99, $P<0.001$). With the avatar, participants recalled almost twice as many vital signs correctly as with conventional monitoring (9 *vs* 5, $P<0.001$). Perceived confidence was improved (2=certain *vs* 1=uncertain, $P<0.001$) and perceived workload lowered (task load index 60 *vs* 76, $P<0.001$). Participants obtained these results only after watching an educational video explaining the avatar and suggesting quick learnability and potential for real-life usability.

Conclusions: This study provides empirical evidence that an animated avatar offers the opportunity to transmit vital sign information significantly more quickly than conventional monitoring and with improved confidence and reduced cognitive effort. This could help care providers gain situation awareness more efficiently.

Keywords: computer-assisted; diagnosis; patient monitoring; situation awareness

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Editor's key points

- Situation awareness is critical in monitoring patient vital signs by anaesthesia professionals.
- A novel technology designed to improve perception of vital sign information, which presents patient status as an animated patient avatar, was compared with conventional monitor data in a simulation scenario.
- With the avatar, participants recalled almost twice as many vital signs correctly compared with conventional monitoring, and perceived confidence was improved and workload lowered.
- Real-life studies are required to confirm that use of an animated avatar can transmit vital sign information more quickly than conventional monitoring.

Situation awareness enables healthcare providers to correctly diagnose patient condition and make informed clinical decisions. This might help care providers to avoid errors and improve patient safety.[1–7] By definition, it comprises three levels: 1) perception of elements in the environment within a volume of time and space; 2) comprehension of their meaning; and 3) projection of their status in the near future.[2] In patients connected to a patient monitor, real-time and trend information from the screen and auditory displays, specifically pulse oximeter tone and acoustic alarms, contribute significantly to care providers' mental model of patient status.[4–6] Therefore, the WHO considers continuous patient monitoring 'extremely important' for the safety of the 313 million surgeries performed worldwide per year.[8,9] The WHO also sees complications of anaesthesia and surgical care as a leading cause of preventable death and disability, and poor situation awareness and decision-making have been recognised as leading factors causing patient harm.[1,8,10–14]

The typical design of current conventional monitors does not optimally enable care providers to gain an understanding of the situation in a time-efficient manner because of the way information is presented. Specifically, vital signs are presented individually as waveforms or numbers using a single sensor, single indicator philosophy. Care providers, in a time-consuming process, must read and interpret each waveform or numerical value one after the other to gain situation awareness.[4,15,16] However, the average time anaesthesiologists spend looking at monitors is only about 2 s, and the need for several glances to detect abnormal values has been reported.[17,18]

To optimise the information gained from checking a monitor, we developed an information transfer technology named Visual Patient. It was our goal to create an interface that transmits the current status of the vital signs to care providers as quickly as possible and with minimal cognitive effort, which has been described as the goal for successful situation awareness design.[2] The Visual Patient integrates information about the 11 most commonly used standard vital signs into visualisations in an animated model of the real patient (a patient avatar) using a multiple sensor multiple indicator approach. Furthermore, the technology reduces the complexity of monitoring data by processing vital signs into two or three visualisation conditions. For vital signs that have a too low, safe, or too high status (e.g. arterial pressure) the avatar can display these three visualisation conditions. For vital signs that can be categorised into an unsafe or safe status (e.g. oxygen saturation) the avatar can display these two conditions. Among the 11 vital signs, 30 different visualisation conditions can be displayed, giving the technology the theoretical capability of displaying a total of 4608 different situations. We used an avatar because previous research has indicated that anatomical representation of information renders a design more intuitive,[4,15,19] which is important for usability, as a significant problem with prior visualisation technologies was that they were too difficult to learn.[4] Using anatomical representations is also in line with logical principles concluding that models should have a meaningful relationship with the reality they mirror.[20]

We completed a comprehensive iterative development process of the avatar and afterwards compared the final version with conventional monitoring. We used a method based on the Situation Awareness Global Assessment Tool,[21] blanking the screens after 3-s and 10-s intervals and measuring outcome measures that have been shown to be essential for situation awareness, decision-making, and performance.[2] We hypothesised that after 3-s and 10-s glances, the Visual Patient monitor would: 1) enable participants to perceive more vital signs; 2) improve perceived confidence; and 3) reduce perceived workload.

Methods

Validation and calibration of the avatar

Before this study, we conducted an extensive iterative development and calibration process of the avatar involving 150 individual anaesthesia professionals in two study centres. The avatar version used in the present study reached an inter-rater reliability of >94% for each of its 30 visualisation conditions and was calibrated in a Delphi process involving 11 senior anaesthesia experts to monitor adult ASA physical status 1 and 2 category patients under general anaesthesia. We report the validation and calibration process in full in the supplementary file titled Validation of the avatar. Table 1, Figure 1, Supplementary Video 1 (educational video), and the supplementary file 'Validation and calibration of the avatar' describe the avatar in detail.

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.bja.2018.04.024Multimedia component 3.

Study participants

Study participants were anaesthesiologists (staff and resident physicians) and nurse anaesthetists with a completed specialisation qualification from the anaesthesia departments of the University Hospital of Zurich and the Kantonsspital Winterthur (KSW)—two teaching hospitals in Switzerland performing approximately 30 000 and 10 000 surgical procedures per year, respectively. Participation was voluntary and the participants received no compensation. We included participants who responded to institutional e-mail invitations and asked colleagues to participate according to their availability. The ethics committee of the Canton of Zurich, Zurich, Switzerland reviewed the study protocol and issued a declaration of no-objection (BASEC-No. Req-2016-00103). All participants gave their written informed consent.

Study design

To compare the avatar with conventional monitoring, we conducted a multi-method laboratory study. The methods