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EDITORIALS

Data visualisation and cognitive ergonomics in anaesthesia and healthcare

Craig S. Webster[1,2,*] and Jennifer M. Weller[1,3]

[1]Centre for Medical and Health Sciences Education, School of Medicine, University of Auckland, Auckland, New Zealand, [2]Department of Anaesthesiology, Faculty of Medical and Health Sciences, University of Auckland, Auckland, New Zealand and [3]Department of Anaesthesia, Auckland City Hospital, Auckland, New Zealand

*Corresponding author. E-mail: c.webster@auckland.ac.nz

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The increasing complexity of patient monitors and data displays in the operating theatre places increasing cognitive demands on clinicians. Greater cognitive demands can lead to errors in patient care, particularly if cognitive load is further increased by a critical event. Little consideration is typically given to the human factors involved in the way in which information is presented to clinicians in the operating theatre, and little usability testing is typically done before new displays are introduced. In this issue of the *British Journal of Anaesthesia*, Roche and colleagues[1] present a study involving 52 anaesthesia teams undergoing 154 high-fidelity simulations using a novel 'humanoid' display format, which addresses some of the known problems in patient monitoring, and does so by making considerably greater use of human factors in the design solution than previous approaches.

The wholesale entry of computerisation into healthcare in recent decades has led to a rapid increase in the number and complexity of patient monitors and displays, particularly in high-intensity treatment areas.[2–4] The clear and cogent display of information in various formats is a well-established area of study in many industries.[5] In particular, computerisation is known to result in the generation of large volumes of data. In the 1990s, the difficulties of displaying such data and making sense of it emerged as a new field of study called information visualisation.[2,6] However, the most common approach for the display of data on patient monitors remains the single-sensor single-indicator (SSSI) paradigm, where the data from each individual sensor are displayed as a separate data element on a computer screen.[7,8] With little standardisation between manufacturers or hospitals in the placement of data elements on displays, including the possibility of the same data element being displayed on more than one monitor, the search time to find relevant information can be increased. In addition, many patient monitors have various different display modes, including the ability to customise displays, which can add further confusion.[9] The presence of many separate SSSI data elements on a display, or series of

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displays, crowds the visual field and leaves it up to the clinician to locate, synthesise, and interpret data elements to determine the status of their patient.

In the solution proposed by Roche and colleagues,[1] multiple separate data elements are combined into a single intuitive display, that of a stylised human form or avatar. Such an approach does more than simply standardise the display, as it groups data elements into a meaningful whole that is the avatar patient itself, a kind of visual mnemonic. Changes in body systems of the patient are displayed by analogy as stylised animated changes in body parts of the avatar; for example, a patient with cyanosis shows the avatar with a purple body, and high blood pressure is shown in the avatar by the outline of the entire body pulsating beyond normal limits. Displaying information in this way makes it more salient and intuitive than separate data elements on a screen. The reasons for this can be better understood if we consider how human brains work.[10]

The human brain is a powerful and intelligent filter, but one with limited working memory. Our senses constantly receive stimuli from the world; yet, most of them are filtered out by the brain before reaching conscious awareness. The information from the world that does get through is first sorted and grouped by meaning. The process of grouping information from the world into meaningful units (the chunking hypothesis) applies to every human activity, and particularly to experts working within their highly practised domain of expertise. One of the classic studies in this area of cognitive psychology involves chess players.[11,12] Chess masters have the same cognitive capacities as novice players; yet, masters are vastly better at determining which sequences of moves will assure them the win and which are not worth considering. Masters achieve this by being able to see the entire chessboard as a small number of meaningful groupings of pieces, each grouping forming a chunk that can be collectively and efficiently processed by limited working memory. Novices lack the ability to see meaningful chunks in the pieces on the chessboard, and so become overwhelmed in considering all possible individual moves. Most remarkably, the chunking skills of masters only work when chess pieces on the board are in meaningful arrangements, such as during a real game of chess.[11,12] In memory recall tests, chess masters are able to reconstruct the position of every piece on a board after glancing at a game in progress for only seconds, but perform almost as poorly as novices when presented with boards of randomly arranged chess pieces.

In the clinical context, clinicians are the experts, and a data display that intuitively and meaningfully groups patient characteristics would be expected to reduce cognitive demands related to synthesising and interpreting data by allowing clinicians to effectively chunk information. Consistent with this idea, in previous work, the avatar-based display has been shown to allow care providers to recall more vital signs with increased diagnostic confidence, and to report reduced levels of workload, in comparison with conventional data displays.[13] In the current study, Roche and colleagues[1] found a 78% increased probability of identifying the cause of an emergency with the use of the avatar display. Clinicians participating in the study had a relative lack of experience with the avatar display, compared with years of experience with conventional methods, and this seems likely to have been an influencing factor in the results of Roche and colleagues.[1] For example, task performance improved significantly over time with increasing use of the avatar display, suggesting a learning effect.

The current study was designed to test the non-inferiority of the avatar display compared with conventional methods, and findings suggest that the avatar is ready to move out of simulation and into a clinical trial. However, the avatar display will likely require further improvements. For example, although the combination of the avatar and side-by-side conventional trend displays was found to be non-inferior to conventional monitoring methods in terms of the primary outcome, the avatar alone showed an inconclusive result in this regard. This may be related to the fact that the current version of the avatar shows only the instantaneous status of the patient, and does not contain historical trend displays that are known to be important in detecting changes in a patient's condition.[14] Future work may therefore involve resolving the best way to incorporate trends display into the avatar format in a similarly integrated and meaningful way as the instantaneous data.

As healthcare becomes more networked and computerised, it is certain that the amount of data that clinicians must navigate to deliver effective patient care will increase dramatically.[4,15] Estimates of the amount of healthcare data generated worldwide each year, including electronic health records, have already increased from 153 exabytes (153×1000^6 bytes) in 2013 to 2 zettabytes (2×1000^7 bytes) in 2020, a 13-fold increase.[16] The 2020 estimate is an amount of digital information equivalent to ~1300 billion full-length feature films. It seems obvious that we will need help in navigating these large amounts of data, and such efforts must carefully consider the cognitive ergonomics involved for clinicians using such solutions. Although avatar displays may seem exotic at present, it is certain that new forms of data presentation will become more commonplace in clinical practice in the near future. Two innovations of this nature worth mentioning are artificial intelligence (AI) and augmented reality (AR).

AI is a broadly defined technical term meaning the ability of a computer system to perform tasks previously requiring human intelligence. Currently, in healthcare, AI is typically used to perform tasks associated with analysing patient symptoms, test results, or medical images, and proposing diagnoses.[17,18] However, AI is good at navigating large volumes of data of all kinds and is likely to appear on patient monitors soon. The second innovation, AR, involves supplementing a clinician's real visual field with virtual elements superimposed over it to provide data displays that do not require the clinician to look away from the task at hand to view them. As with all information technology, such innovations tend to complement or supplement each other. For example, the superimposed data display in AR could be generated through AI. The aim with these kinds of technologies in healthcare should be that they leverage natural human abilities to improve performance.[17,19] The avatar-based display in the paper by Roche and colleagues[1] is significant because it represents a shift away from the *status quo* of the SSSI paradigm, and may be the first step towards the future of smarter and more ergonomically appropriate display formats.

Authors' contributions

Conceptualisation: CSW
Drafting of paper: both authors
Approval of final version: both authors.

Declarations of interest

CSW is a minor shareholder in SaferSleep LLC, a company that manufactures an anaesthesia record system. JMW is a member of the editorial board of the *British Journal of Anaesthesia*.

References

1. Roche TR, Said S, Braun J, et al. Avatar-based patient monitoring in critical anaesthesia events: a randomised high-fidelity simulation study. *Br J Anaesth* 2021; **126**: 1046–54
2. Few S. *Data visualization past, present, and future: Cognos Innovation Center* 2007. Available from: http://mail.perceptualedge.com/articles/Whitepapers/Data_Visualization.pdf. [Accessed 13 January 2021]
3. Hagenouw RRPM. Should we be alarmed by our alarms? *Curr Opin Anaesthesiol* 2007; **20**: 590–4
4. Wachter R. *The digital doctor: hope, hype, and harm at the dawn of medicine's computer age*. New York: McGraw–Hill; 2017
5. Tufte ER. *Visual explanations—images and quantities, evidence and narrative*. Cheshire, CT: Graphics Press; 1997
6. Card SK, Mackinlay JD, Shneiderman B, editors. *Readings in information visualization—using vision to think*. San Francisco, CA: Morgan Kaufmann; 1999
7. Bitterman N. Technologies and solutions for data display in the operating room. *J Clin Monit Comput* 2006; **20**: 165–73
8. Kiefer N, Hoeft A. Display of information in the operating room. *Curr Opin Anaesthesiol* 2010; **23**: 772–7
9. Sarter NB, Woods DD. How in the world did we ever get into that mode? Mode error and awareness in supervisory control. *Hum Factor.* 1995; **37**: 5–19
10. Reason J. *Human error*. Cambridge: Cambridge University Press; 1990
11. Chase WG, Simon HA. Perceptions in chess. *Cogn Psychol* 1973; **4**: 55–81
12. Gobet F, Lane PCR, Croker S, et al. Chunking mechanisms in human learning. *Trends Cogn Sci* 2001; **5**: 236–43
13. Garot O, Rossler J, Pfarr J, et al. Avatar-based versus conventional vital sign display in a central monitor for monitoring multiple patients: a multicenter computer-based laboratory study. *BMC Med Inform Decis Mak* 2020; **20**: 26
14. Kennedy RR, Merry AF, Warman GR, et al. The influence of various graphical and numeric trend display formats on the detection of simulated changes. *Anaesthesia* 2009; **64**: 1186–91
15. Webster CS, Henderson R, Merry AF. Sustainable quality and safety improvement in healthcare: further lessons from the aviation industry. *Br J Anaesth* 2020; **125**: 425–9
16. Statista. Total amount of global healthcare data generated in 2013 and a projection for 2020. Available from: https://www.statista.com/statistics/1037970/global-healthcare-data-volume/(accessed 13 January 2021).
17. Webster CS. Artificial intelligence and the adoption of new technology in medical education. *Med Educ* 2021; **55**: 6–7
18. Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. *Nat Med* 2019; **25**: 44–56
19. Norman DA. *Things that make us smart: defending human attributes in the age of the machine*. New York: Basic Books; 1994

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Preprints in perioperative medicine: immediacy for the greater good

Rupert M. Pearse[1,2,*], Gareth L. Ackland[1,2], Takashi Asai[3] and Hugh C. Hemmings Jr.[4,*]

[1]William Harvey Research Institute, London, UK, [2]Barts and The London School of Medicine and Dentistry, Queen Mary University of London, London, UK, [3]Department of Anesthesiology, Dokkyo Medical University Saitama Medical Centre, Koshigaya, Japan and [4]Departments of Anesthesiology and Pharmacology, Weill Cornell Medicine, New York, NY, USA

*Corresponding author. E-mails: r.pearse@qmul.ac.uk, hchemmi@med.cornell.edu

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Medical and scientific journals spread developing knowledge by facilitating communication between physicians and scientists. Authors, readers, and the public rightfully expect rapid publication of rigorously reviewed high-quality papers. The COVID-19 pandemic has highlighted the importance of rapid dissemination and has put unprecedented demands on journals. There is genuine urgency to complete medical research and place the findings expeditiously into the public domain after expert peer review so that new findings can be used to improve patient care as soon as possible. The process of peer review is often a slow process, but is essential to ensure that changes in patient care are informed by careful and definitive research. Thus, journal editors must balance the potentially competing goals of immediacy and quality control.