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Learning though high-fidelity anaesthetic simulation: The role of episodic memory

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In this issue, Boet and colleagues investigate skill retention after high-fidelity simulator training for percutaneous cricothyroidotomy insertion [1]. This is an infrequently performed procedure particularly susceptible to error. A recent study by Cook and colleagues found a 75% failure rate (six out of eight) in performance of the procedure in UK intensive care units and emergency departments [2]. Failures were related to a lack of training and technical difficulties. A key recommendation to improve performance was using high-fidelity simulation to teach trainees to recognise the key physical patient landmarks associated with cricothyroidotomy insertion. The findings by Boet and colleagues lend weight to this solution. They found attending anaesthetists to retain cricothyroidotomy crisis management skills for up to one year after participating in a single cannot intubate, cannot ventilate (CICV) scenario. In a post-training event (either six months or a year after initial training) attending anaesthetists recognised scenarios where percutaneous cricothyroidotomy insertion was required, and applied the relevant knowledge and procedural skills for managing the situation. A number of explanations are provided to account for this retention of skills. These include the high-fidelity nature of the training scenarios, the involvement of fully trained anaesthetists, and the memorability of training episodes. Developing this last point, Boet and colleagues invoke episodic memory theory to understand skill retention. Episodic memory theory was proposed by Endel Tulving [3], and it refers to the ability of humans to remember and consciously re-experience past events from their lives either at will or on prompting

As indicated above, high-fidelity simulator training provides anaesthetists opportunities to develop their technical and non-technical skills for managing rare and dangerous scenarios. It provides a safe multidisciplinary learning environment, and depending on training objectives, simulators can replicate a specific aspect of a clinical task or an entire working environment [4]. However, for simulator training to be successful, anaesthetists must behave similarly in real and simulated environments, and it is essential that training scenarios and the tools used to measure performance are reliable and valid [5]. Furthermore, if high-fidelity simulation is to replace elements of class-based teaching in anaesthesia, it is also necessary to consider how it might enhance learning and practice [6]. The cognitive psychology literature has much to offer in this respect, and as indicated by Boet and colleagues [1], episodic memory is especially relevant. Through identifying the psychological mechanisms and aspects of simulation that support learning and practice in anaesthesia, we can optimise the design of high-fidelity simulator training.

Episodic memory and high-fidelity simulation

The episodic memory system represents a holistic approach to understanding human memory, and it relates to the encoding, storage, and retrieval of information learnt during personally experienced situations and events [7]. Episodic memories are centred on the self, with information on context (e.g. the situation) and content (i.e. what was done or learnt) of an experience being linked together. Recalling an ‘episode’ can involve bringing to mind a vast range of information associated with an event, for example visual characteristics, smell and taste, emotional and physical sensations, behaviours undertaken, and knowledge learnt. Experimental psychology and neuropsychological research shows episodic memories to be created through the medial temporal lobe ‘binding together’ the various neurological traces of an episode [7 8]. The left pre-frontal cortex is important for encoding and storage, and the right pre-frontal cortex for retrieval. An event need only be experienced once for information associated with it to be encoded, stored, and made retrievable, with the detail and length of retention depending on factors such as event significance, uniqueness, and memory rehearsal. Depending on memory encoding and storage (e.g. prominence in one's mind, associations between elements of a memory), memories can be retrieved at will through a mental search and retrieve strategy, or by a prompt that automatically activates memory recall.

Due to the experiential nature of high-fidelity simulator training, episodic memory appears relevant for understanding learning. Typically during simulation, anaesthetists perform sensemaking activities to understand a time-limited and realistic event. They employ technical and non-technical skills to manage scenarios and cooperate with team members, and the knowledge and skills learnt through training is contextually bound to a specific situation (e.g. cannot intubate, cannot ventilate scenarios). Similarly, episodic theory posits that episodic memories bind together the context (e.g. scenario) and content (e.g. knowledge learnt) associated with an event. Memory retrieval is enhanced when the cues of the recall environment are similar to those in the learning environment [9]. A key advantage of simulator training is that it helps anaesthetists to develop knowledge and skills for rarely seen scenarios. However, if behavioural strategies have not been learnt to a degree whereby they are 'automatically' used to manage an event, the deployment of skills and knowledge learnt during simulation surely depends on anaesthetists i) recognising cues within a real-life event that are analogous to a simulated episode, and ii) consciously recollecting the knowledge and behavioural strategies used previously to manage that event. As episodic memory theory describes factors that influence the encoding and retrieval of such experiences, it may provide a useful framework to consider how the design of training scenarios can support learning.

Using episodic memory to understand learning from high-fidelity anaesthetic simulation

Simulation research in anaesthesia focuses upon the validity, reliability, feasibility and learning effects from high-fidelity simulator training [5]. Furthermore, theoretical analyses have established standards for the expected properties of simulated training scenarios (e.g. fidelity, physiological modelling) [10]. However, there is also a need to understand the factors that make a simulated training scenario an effective teaching instrument for influencing anaesthetic practice. Thus, it is worth discussing briefly the pedagogic advantages of simulator training, and then considering how episodic memory theory might advance our understanding of learning through anaesthetic simulation.

The learning objectives of simulator-based training in anaesthesia vary according to a variety of factors (e.g. expertise, knowledge, skill development). Consistent with the episodic memory perspective, simulator training teaches participants to recognise scenarios (e.g. CICV), and to apply the requisite memorised technical and non-technical skills for managing the scenario [6]. Factors such as existing knowledge, experience, and opportunities for practice in real-life and simulation will influence the extent to which skills and knowledge become integrated into practice. The pedagogic literature supports the assumption underlying that simulator based training will aid learning. For example, the extent to which a training task is physical (e.g. manual application of a skill) and natural (e.g. realistic) improves skill retention and future application, as does the similarity of learning and practice environment [11]. In addition, constructivist theories argue that learning is successful when the gap between actual and intended knowledge of trainees is identified, and training is structured so that participants can sense-make and problem solve to reduce this gap [12]. This perspective is consistent with simulation, with participants being afforded a safe learning space where they can apply their skills and knowledge to solve challenging problems designed by experts.

Thus, from a pedagogic perspective, there is good evidence to assume that simulator training will facilitate learning. However as discussed in the section above, learning and practice after simulation may be dependent on the quality and ability to recall training episodes. This is particularly the case for rare or unexpected events, as there are less opportunities for the skills and knowledge used to manage those events to become well practiced, and to enter into routine behaviour. The episodic perspective would appear to indicate at least two factors as important for ensuring learning and future application. Firstly, the memorability of training scenarios. It would appear logical that details associated with an anaesthetic simulated event (e.g. patient illness, environment, cues that prompted decision-making, behavioural strategies) will be encoded and recalled in higher levels of detail if simulated training events are noteworthy in some dimension (e.g. novel, enjoyable, challenging, successful). A second factor is the extent to which cues used in high-fidelity simulator scenarios to influence decision-making are analogous to real-life. Episodic memory theory appears to indicate that the fidelity of scenarios will be important for future recall, particularly with rare or unusual events. Specifically, the extent to which there is similarity between simulated and real-life cues will increase the likelihood that decision-making strategies learnt during simulation are recalled in practice. This is consistent with the expert decision-making literature, with decision-making being influenced by the recall of strategies used to manage a previous similar event [13].

It is notable that the existing literature on high-fidelity anaesthetic simulator training also provides insight and speculation into how episodic memory systems might support learning, retention and recall. For example, research investigating critical event training (e.g. requiring use of an Advanced Cardiac Life Support protocol) has shown that the detailed debriefing of participants after a training scenario results in improved performance on a re-test scenario six to nine months later [14]. From an episodic perspective, debriefings provide trainees with an opportunity to reflect upon their practice and consolidate memories. By watching one's performance, and noting the key situational cues and resultant problem-solving and behavioural strategies, learning may be reinforced through providing participants an opportunity to retrieve and mentally rehearse key aspects of the training episode.

The design of simulator scenarios also appears important for learning and future recall of knowledge and skills associated with an episode. A study investigating oesophageal intubations found anaesthetist' performance not to improve when participating in a second simulated training scenario [15]. The study cites various reasons for this, with it being indicated that that anaesthetists may have focused on aspects of the simulation episode (e.g. haemorrhagic shock), rather than the technical learning goals (e.g. solutions for managing oesophageal intubation). Episodic memory theory does not specify limitations on the volume and detail of information that can be encoded and stored within a single episode. However, it would appear logical that anaesthetists who participate in highly stimulating scenarios attention may become overly focused on the context of a scenario (due to its intensity) rather than the solutions (which may not appear apparent or remarkable in comparison). As Boet and colleagues [1] indicate, this effect may be more pronounced for trainees rather than experienced specialists. It perhaps speaks to the need to design scenarios which are memorable and have clear solutions, but are not overwhelming in terms of information or pressure.

Simulator research has also provided some support for the proposal that knowledge and skills associated with specific anaesthetic scenarios will increase the likelihood of them being used in practice. For example, in a study of standard operating procedures used to prevent aspiration during rapid sequence inductions (RSI), trainee knowledge was assessed through questionnaires or simulated scenarios [16]. The simulation group tended to employ highly routinised rapid procedures more frequently than the questionnaire group. Alternatively, they did not utilise to the same extent procedures cited as important by the questionnaire group (e.g. implementing semi-sitting position). This is consistent with episodic memory theory, as if knowledge of anaesthetic procedures are not contextually ‘bound’ to a scenario (i.e. they are learnt in a classroom setting) it may be less likely they are applied during practice or simulation.

Recent research by Bruppacher et al [17] lends some weight to this point. In comparison to a control group, anaesthetists who participated in simulator training for weaning patients from cardiopulmonary bypass (CPB) demonstrated improved technical and non-technical skill in post-test assessments of real practice. Simulator training was incremental, and participants performed in four high-fidelity CPB scenarios (each with slightly different challenges) and then were debriefed. After two and five weeks, anaesthetists weaned real CPB patients, and those who participated in the simulator training demonstrated enhanced performance (compared to those attending interactive seminars). Although such events are not rare, the findings resonate with episodic memory theory, with memories for knowledge and skills being associated with an event in high-fidelity simulation and then utilised in real practice. Furthermore, through using a series of scenarios to explore different aspects of task performance, it is consistent with pedagogic theory on the benefits of structuring problem solving tasks to incrementally aid learning. Simulator training can also be used to carefully identify trainee knowledge gaps and the simulated problem-solving tasks that will support learning. For example, anaesthetic scenarios of varying complexity have been used to distinguish between early-stage training anaesthetists and later-stage or fully trained anaesthetists [18].

Finally, although anaesthetic high-fidelity simulator training has been shown to improve technical and non-technical skills, the extent to which training will continually develop the skills of anaesthetists may depend on the continual development of scenarios. For example, anaesthetists who attend a high-fidelity anaesthetic crisis management scenario just once demonstrate improvements in their non-technical skills [19]. However, when participants partake in further training sessions their skill levels do not continue to improve. Episodic memory systems are sometimes considered to be 'one-shot' in nature, whereby the content and context of an experience are bound together to a specific event or moment. Repeating a training event or a near equivalent may consolidate or reinforce the existing performance strategies that have been associated with a specific situation (helping behavioural strategies to be more instinctively applied). However, as described above, to further facilitate knowledge and skill development trainees will need to experience new events which allow them to sense-make and solve memorable and distinct problems.

Final reflections

As high-fidelity simulation becomes more widely used in anaesthetic training, it is increasingly important that we understand how simulation is expected to influence learning and practice. Table 1 lists the key conclusions from the above discussion on factors that may influence learning and practice after high-fidelity simulation training in anaesthesia. In particular, episodic memory theory may provide a useful framework to understand the pedagogic value of high-fidelity simulator training for rare training events. At present this proposal is speculative, yet it is not inconsistent with decision-making and pedagogic theory. However, it must be noted that several critiques have been made of the episodic memory perspective.

INSERT TABLE 1 HERE

Within the psychology community, episodic memory systems have been criticised due to their reliance upon networks of cortical and sub-cortical brain regions [7]. This makes it difficult for psychologists to differentiate between memories using classical forms of memory categorisation [20]. Also, episodic memory theory is a relatively new and developing field, and new discoveries are constantly emerging. For example, research shows similarities between the neural processes used to recall an episode, and those used to imagine a future event [21]. Factors such as age [22] and sleep [23] influence the formation of new episodic memories, and a variety of factors can result in memories being incorrectly encoded or retrieved [24]. Finally, it must be noted that numerous other memory systems influence learning. For example, the retrieval of information is influenced by presentational order of data [25]. These findings do not run counter to episodic memory theory; rather they highlight the extent to which the design of simulator training can benefit from increasingly adopting principles from cognitive science. As the use of high-fidelity simulation increases in anaesthetic training, so must our understanding of how we expect simulation to influence the learning and practice of anaesthetists.

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Table 1. Six factors that may influence learning and practice after high-fidelity simulator in anaesthesia

Steps	Description
1. Scenario memorability	Simulator training scenarios that are distinct or noteworthy in some dimension (e.g. novel, enjoyable) may enhance the memorability of the cues connected with that scenario and the relevant behavioural strategies. This appears particularly important for the simulation of rare anaesthetic events.
2. Similarities between simulation and practice	To support anaesthetists recalling the decision-making strategies used to manage an event in simulation, the cues designed to influence decision-making in a simulator scenario should demonstrate high-fidelity in order to prompt recognition and recall in practice
3. Debriefing participants	Video-supported debriefing after simulator training will provide anaesthetists with the opportunity to i) note the key situational cues and associated problem-solving strategies associated with a particular anaesthetic scenario, and ii) unconsciously consolidate and rehearse their memories for key elements of the training episode.
4. Avoiding overly complex training scenarios	For training scenarios that are overly stimulating or complex, learning for routine aspects of scenario management may be sub-optimal due to participant's being overly focussed on situational context (e.g. managing stress) and not problem-solving. This is particularly the case for trainee anaesthetists, who may become overwhelmed by the pressure of a training episode.
5. Incrementally introducing new problems-solving tasks	For training intricate problem-solving or technical skills, dividing scenarios into smaller elements may aid learning. Specifically, incremental problem-solving will allow participants to identify and learn solutions for the different problems that may be faced during a complex anaesthetic scenario. This will be especially beneficial for trainees. However, for crisis management training, training events should unfold as they would in reality (i.e. managing a crisis until its conclusion).
6. Refreshing the content of training scenarios	To continually enhance the technical or non-technical skills of anaesthetists, new and challenging training scenarios will need to be developed. Participants who attend repeated anaesthetic simulated training events may reinforce, but not further develop, the skills learnt during the initial stages of training.