

Expertise in medicine: using the expert performance approach to improve simulation training

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CONTEXT We critically review how medical education can benefit from systematic use of the expert performance approach as a framework for measuring and enhancing clinical practice. We discuss how the expert performance approach can be used to better understand the mechanisms underpinning superior performance among health care providers and how the framework can be applied to create simulated learning environments that present increased opportunities to engage in deliberate practice.

EXPERT PERFORMANCE APPROACH The expert performance approach is a systematic, evidence-based framework for measuring and analysing superior performance. It has been applied in a variety of domains, but has so far been relatively neglected in medicine and health care. Here we outline the framework and demonstrate how it can be effectively applied to medical education.

DELIBERATE PRACTICE Deliberate practice is defined as a structured and reflective

activity, which is designed to develop a critical aspect of performance. Deliberate practice provides an opportunity for error detection and correction, repetition, access to feedback and requires maximal effort, complete concentration and full attention. We provide guidance on how to structure simulated learning environments to encourage the accumulation of deliberate practice.

CONCLUSIONS We highlight the role of simulation-based training in conjunction with deliberate practice activities such as reflection, rehearsal, trial-and-error learning and feedback in improving the quality of patient care. We argue that the development of expertise in health care is directly related to the systematic identification and improvement of quantifiable performance metrics. In order to optimise the training of expert health care providers, advances in simulation technology need to be coupled with effective instructional systems design, with the latter being strongly guided by empirical research from the learning and cognitive sciences.

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INTRODUCTION

Significant variation in clinical competencies exists between individual health care providers that may contribute to a large variation in patient outcomes and inefficient use of resources.¹ Although increasing experience plays an essential role in achieving proficiency, completing more procedures does not necessarily ensure that expertise will be attained if reflection, feedback and learning are limited.² The development of expertise is thought to be a consequence of the amount of domain-specific deliberate practice accumulated by individuals throughout their career, rather than mere exposure to the performance domain. Deliberate practice is defined as a ‘structured activity, which is designed to develop a critical aspect of current performance’.³ Deliberate practice provides an opportunity for error detection and correction, repetition, access to feedback, complete concentration and full attention.³

Developing expertise in health care relates to the systematic identification and improvement of quantifiable performance metrics. In this review, we focus on the effectiveness of simulation in helping to identify and facilitate development of the critical skills that underpin expert performance in health care. Specifically, we review the expert performance approach³ and how it can be utilised to help capture, develop and sustain expertise in health care delivery. We identify advances in simulation technology and explore how the expert performance approach can be integrated into medical

education to provide effective and efficient training. Although this is not a systematic review, we conduct a thorough review of the literature on simulation and its use in medicine and provide support for the arguments, discussions and suggestions outlined.

EXPERT PERFORMANCE APPROACH

An individual’s experience in a given domain is not always correlated to improved performance outcome, in fact, it can be negatively related.⁴ For example, experts in decision making and judgement often fail to display superior performance accuracy, especially in tasks involving predictions of future outcomes when compared with less experienced or skilled counterparts.⁵ Ericsson and Smith⁶ introduced the expert performance approach in response to this apparent dissonance between professional experience and indicators of expertise. The approach presents a systematic, evidence-based framework for measuring and analysing superior performance in a domain rather than studying the differences between individuals viewed as experts and novices, respectively, through subjective, peer-based review.^{7,8}

Ericsson and Smith⁶ suggest that those studying expertise should focus on trying to capture performance using reliable and objective measures. They present a three-stage framework for capturing and developing expertise (see Fig. 1). First, researchers must recreate the task(s) in the laboratory or field

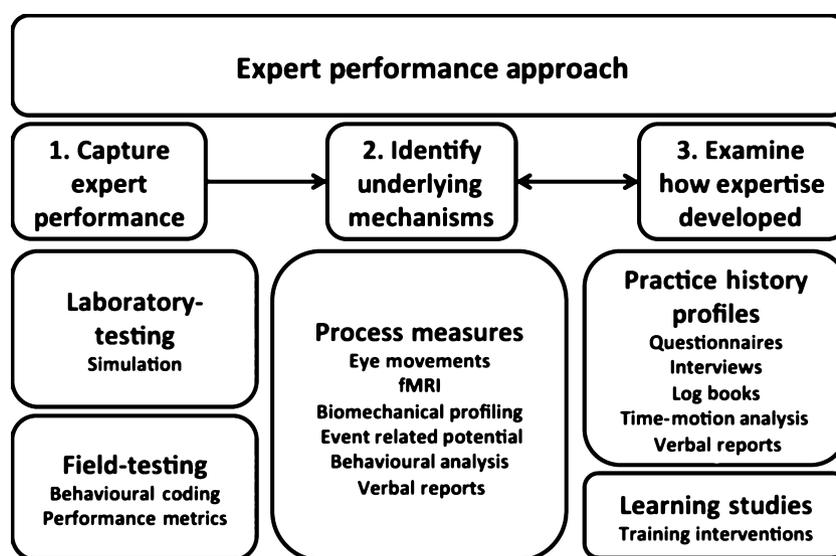


Figure 1 Outline of the expert performance approach

with sufficient fidelity to elicit the requisite expertise in a reliable and objective manner. Second, the mechanisms underpinning superior performance should be identified using experimental manipulations and process-tracing measures. Third, activities that lead to performance improvements need to be identified so that the path to competency is clearly defined and can be targeted for training and development. The framework has been successfully utilised in many professional domains, such as in sport⁸ and the military,⁹ but has not been broadly deployed in health care. In this review, we discuss how this framework can be used to develop more effective and efficient training environments for health care professionals. In particular, we focus on the potential role that simulation in all its various guises may play in providing objective, reliable and valid methods to capture, assess and enhance expertise in health care.

Stage 1: Capturing expert performance

In this initial stage of the expert performance approach, the emphasis is on creating scenarios and environments that are representative of the real world and elicit the same perceptual and cognitive processes. In health care, the use of simulated environments is becoming more prevalent and the technology more advanced, providing opportunities to create representative environments for testing and training.¹⁰ The types of simulator are varied, including, for example, complex task trainers for endoscopic- and catheter-based procedures, ultrasound simulators, standardised patients, computer-based case simulations, full-length mannequin computer-controlled simulators and surgical devices incorporating touch, audio and visual simulation.^{11,12} Virtual reality devices are also rapidly reaching an early stage of implementation.¹³ These environments allow educators to provide repeatable, controlled clinical scenarios that can closely match the demands of a real-world task (stage 1 in Fig. 1) without jeopardising patient health.¹⁴ Simulators and virtual reality environments are currently being utilised in various medical domains, such as in cardiovascular medicine,¹⁵ emergency medicine,¹⁶ midwifery¹⁷ and gynaecology.¹⁸ The data gathered in these studies suggest that simulation-based mastery and learning exercises that embrace the principles of deliberate practice can be used to improve the performance of complex skills.

However, concerns remain when using simulations for training and performance enhancement, particularly in regards to the validity of the measurements

and methods employed and the extent to which they adequately capture the demands and complexity of the real world.^{19,20} Historically, there have been concerns about the physical and psychological fidelity of simulators.²¹ The early simulators were low in fidelity and did not allow 'real-world' representations to be accurately produced and, therefore, differences as a function of expertise were difficult to ascertain.¹ More recently, high-fidelity simulators have been developed that better recreate the demands of the operating theatre and hospital wards, providing an opportunity to more accurately measure expertise. Several recent reports provide a modicum of construct validity for the use of simulators in health care. For example, Cormier *et al.*²² used a high-fidelity medical simulation to distinguish between low- and high-performing student nurses based on their ability to prioritise patient care more effectively. Similarly, Schijven and Jakimowicz²³ highlighted the potential of simulations to differentiate expert from novice surgical providers. These authors used a simulation task that required clipping and cutting the cystic duct and artery during a laparoscopic cholecystectomy. A group of expert and novice surgeons were familiarised with the simulator and each performed the task three times. The expert group scored significantly higher on the second and third attempts when compared with the novice group. Moreover, the experts demonstrated significantly faster completion times on all three attempts. These results demonstrate the potential application of simulators in providing a representative task to examine skill-based differences in surgical skills.^{24,25} It is important to note that there were no differences in performance between the two groups in the first trial. This latter finding suggests that there is a need to provide sufficient opportunity for providers to familiarise themselves with the simulator in order to become comfortable with the demands and constraints of the task.

Although recent published reports have clearly highlighted the potential value of using simulators to capture expert performance in health care settings, there remain opportunities to capture expertise *in situ* during routine medical procedures. For example, it is possible to capture certain process-tracing measures (see Fig. 1; discussed in more detail in stage 2), such as verbal reports, video-based coding of behaviours and movement efficiency, and point-of-gaze data *in situ*.¹ The collection of such data could easily be implemented in less complex and more frequent activities, such as during ward rounds, X-ray and scan analyses and in general patient assessment. However, the use of such

invasive measures may prove more difficult in tasks such as surgery, as the complexity of the real-world scenario varies, and cases are often unpredictable, and difficult to control and reproduce key variables. In these latter cases, simulators offer several advantages due to their ability to present reproducible and controlled environments that eliminate risks to patient safety.²⁶ Clearly, a suitable balance is required between the need to maintain external or ecological validity on the one hand and the desire for internal validity and experimental control on the other.

In summary, in many instances, simulators offer health care providers the closest environment to the real world that is currently possible without compromising patient care. Clearly, researchers and expert clinicians need to pool knowledge and engage in meaningful discussions as to how best to develop the most representative task environments.²⁷ It is critical that these tasks engage the same knowledge structures and perceptual-cognitive processes that are used in real patient care so as to ensure that performance is accurately captured and an appropriate opportunity is provided for training and development.

Stage 2: Identifying mechanisms underlying expertise

Once a representative task has been developed, the specific mechanisms, knowledge structures and technical abilities needed to successfully complete the task can be measured. Process measures, such as verbal reports, gaze behaviours, movement efficiency and behavioural analysis, can identify the concurrent processes that mediate individual differences during superior performance^{8,28} (see Fig. S1). The effectiveness of each of these measures and how they have previously been applied in a medical setting is discussed below.

Think-aloud verbal protocols, both concurrent and retrospective, have been used to reveal the refined knowledge and reasoning strategies underpinning superior performance.²⁹ These techniques are useful to identify the domain-specific knowledge that experts utilise in order to perform the task. For example, Lesgold *et al.*³⁰ reported that expert radiologists demonstrate longer reasoning chains with more of their comments being interlinked and interconnected to at least one other chain. These findings highlight how experts store and organise knowledge in a more coherent manner, enabling them to better access and retrieve this information to solve simple tasks.

Verbal reports can also be used to identify cognitive structures in complex tasks. Joseph and Patel³¹ examined how domain-specific knowledge impacts on diagnostic reasoning by collecting retrospective verbal reports. A sample of experts (endocrinologists) and non-experts (cardiologists) were asked to solve a range of endocrine cases. The expert group selected more relevant and critical cues from the case history compared with the non-expert group, who focused on significantly more irrelevant cues. The experts generated more links to related critical or relevant cues and showed better organisation of their domain knowledge.

This domain-specific knowledge can be critical when key information is unavailable. McRobert *et al.*³² examined skill-based differences in cognitive processes and how they are altered as a function of removing context-specific information related to the patient's medical condition. The results suggest that experts employ complex domain-specific memory representations that enable them to easily retrieve task-specific information and make better judgements compared with less expert counterparts.^{33,34}

It is clear from the information presented above that experts are accessing a considerable bank of domain-specific information that is seemingly available instantly, suggesting a more efficient memory retrieval system. According to the long-term working memory theory,³³ skilled individuals are able to bypass the limitations in storage by acquiring skills that encode information with numerous and elaborate retrieval cues that are related to prior knowledge. The time required to encode and retrieve options is reduced with the development of retrieval structures through an extended period of deliberate practice. After extensive practice in the domain, experts index information in such a way that they can successfully anticipate future retrieval demands and quickly update the knowledge they need to address the question or challenge at hand. If representative tasks can be developed that enable practitioners to sustain engagement in domain-specific deliberate practice, critical knowledge structures and more efficient memory processes could be developed over time.

Ericsson and colleagues proposed the long-term working memory theory to explain how experts can reduce the amount of information needed to create a coherent representation of the visual scene by selectively attending to only the pertinent

information in the display. Expert performance in many domains is characterised by fewer fixations of longer duration, supporting the premise that experts extract more task-relevant information from each fixation. For example, Law *et al.*³⁵ examined the eye movements of expert and novice surgeons performing a one-handed task on a computer-based laparoscopic surgery simulator. The novice group required more visual feedback when compared with experts about the tool position needed to complete the task. The experts had a tendency to maintain their gaze on the target, while manipulating the tool and monitoring its movement in the periphery, whereas the novice group demonstrated a much more variable gaze pattern, fixating on the tool and target intermittently. These findings were corroborated by Wilson *et al.*,³⁶ who found that experienced surgeons employed significantly longer fixation durations on the target location than novices in a virtual laparoscopy surgical task. These data suggest that by measuring gaze strategies, researchers can identify critical visual information that experts use in order to plan and control their movements when attempting to complete complex clinical tasks.

As well as using more efficient gaze behaviours and elaborate memory structures, experts tend to have more efficient motor control strategies. Experts usually take less time and less effort to complete tasks. For example, Richards *et al.*³⁷ examined instrument forces and torque applied during a cholecystectomy and a Nissen fundoplication in a pig model between expert and novice surgeons. Lower forces and torques were identified in novices during tissue dissection, whereas experts demonstrated higher forces and torques when performing tissue manipulation. Novice surgeons required significantly more time to complete the task and made more non-goal-oriented movements compared with their expert counterparts while applying larger forces and torques when not needed. These data highlight more effective and efficient methods of completing clinical tasks in order to provide accurate training and instruction for those learning novel tasks.

In summary, a range of process-tracing measures may be recorded during simulation (or *in situ*) in order to develop a comprehensive representation of expertise in a given task. Once identified, medical educators can design and implement specific training environments and interventions integrating deliberate practice that enable the underlying processes and mechanisms to be developed.

Stage 3: Acquiring expertise

The relationship between expert performance and the volume of domain-specific deliberate practice has been consistently demonstrated across diverse professional domains, including sport,³⁸ music,³ business,³⁹ nursing⁷ and academia.^{40,41} These studies suggest that engagement in structured practice leads to the development of task-specific knowledge that helps skilled individuals focus their attention on more pertinent areas of the display, making it easier to surmise situational probabilities from events previously experienced. These task-specific adaptations enable the more effective processing of contextual information.⁴² Medical simulators enable individuals and teams of professionals to engage in safe learning scenarios that involve feedback, the repetition of skills, processes and procedures, detect and solve errors or diagnostic problems, within an environment that requires full attention and concentration.^{43,44} For example, simulators can accurately mirror human responses to such procedures as induction of general anaesthesia, tracheal intubation and cardiopulmonary resuscitation, including proper chest compressions with adequate force. Such capabilities provide controlled opportunities for systematic learning and the deliberate practice of a wide range of cognitive and technical skills^{45,46} in scenarios representative of real patient care.^{41,42}

The benefits of deliberate practice in the medical domain have been documented. For example, Wayne *et al.*⁴⁷ examined the role of deliberate practice on the ability of surgical residents to master thoracentesis skills. Performance of the clinical skills test improved by 71%, with all residents exceeding the mastery standard. The accumulation of medical knowledge can also be improved with deliberate practice. Moulart *et al.*⁴⁸ examined the effects of deliberate practice on the academic achievements of medical students. Positive correlations were reported demonstrating the impact of deliberate practice on academic performance. Furthermore, McGaghie *et al.*⁴⁹ conducted a meta-analysis of the effects of practice and learning outcomes in medical-based simulation training. A strong association was reported between the hours of deliberate practice accumulated on the medical simulators and their standardised learning outcomes. Similarly, Issenberg *et al.*⁵⁰ reported that high-fidelity medical simulations facilitate learning. The results from these meta-analyses demonstrate the need to integrate the deliberate practice framework in training to achieve more effective skill acquisition.

Although significant effects have been reported in training studies involving the use of simulators, most of these reports lack the scientific rigor employed in other non-clinical domains.¹ Several papers report less than rigorous experimental designs, using descriptive and subjective performance measures. Traditional experimental designs involving pre- and post-test measures of performance and appropriate measures of retention and transfer are rare. There have been no attempts to record process-tracing measures during acquisition to ascertain how the underlying processes and mechanisms alter with practice.¹ Such inconsistencies and poor experimental designs have led to inconclusive findings that limit the ability to generalise findings to other domains or scenarios. Scientific literature from other domains, such as from sport²¹ and the military,⁵¹ provide examples of how to develop more suitable experimental designs to determine the most effective learning environments for using simulators. This latter body of literature highlights the need to create an environment where students and trainees can perform repetitive behaviours and receive feedback and instruction to ensure the development of key skills. These environments should be challenging and individuals should be encouraged to detect their errors, reflect on their workflow and outcomes, and correct their own errors.

A particular benefit of simulations is that they enable clinicians to attempt the most challenging and demanding cases and engage in trial and error learning and problem solving without putting the safety of patients at risk.¹¹ Critical cases, which may arise infrequently in clinical settings, can be reproduced in a simulation providing greater opportunity for deliberate practice. Simulators also open up possibilities for scenario simulation, where decision-making is multilayered and context specific⁵² (stage 3 in Fig. 1). For example, scenarios that involve large teams, working with missing or incorrect information and with unexpected or complicated cases regularly seen in a real-world environment, are easily replicated in a simulation.

CONCLUSIONS

We argue that the development of expertise in health care is directly related to the systematic identification and improvement of quantifiable performance metrics. Moreover, in order to develop expert and safe providers of health care, supervised practice must start at a very early stage of training and, importantly, must be maintained at high daily

levels for many years, perhaps a decade or more.³ The effects of extended deliberate practice, coaching and feedback, on performance are more far-reaching than is commonly believed and might explain why centralisation of highly specialised care, such as cancer, paediatric cardiac surgery, cystic fibrosis and more, requires high volumes of practice by the entire clinical microsystem.^{53–55}

We propose that the expert performance approach offers a systematic framework to capture and facilitate performance in health care settings. Furthermore, the evidence, albeit mostly from non-medical fields and increasingly in health care, is that despite anecdotal reports suggesting that expert performance reflects innate abilities and capacities or the passive accumulation of experience, expertise actually arises through prolonged and dedicated engagement in deliberate practice activities. An extended engagement in well-structured, domain-specific deliberate practice in suitable environments can expedite skill development. We believe that health providers can develop mechanisms that contravene the basic working memory capacity and processing limits by using simulation in all its various guises linked with deliberate practice. We suggest that the scientific study of expert performance can improve understanding of the limits and structure of human adaptation as well as assist in creating safe training environments and structures that lead to improved health care provision. The framework might also help to understand how the expert performance model can be applied to teams and lead to sustained, high-performing clinical microsystems.

It is clear that there are a number of variables that determine whether, and how long, it will take an individual to achieve expertise in health care. There appears to be a strong case for promoting engagement in deliberate practice activities that allow the build-up of domain-specific declarative and procedural knowledge. Physical and virtual-reality simulators offer an opportunity to engage in these practice behaviours under controlled conditions. Educators should be encouraged to embrace new technology to develop a more interactive and ecologically valid learning environment.

More research is needed to establish a stronger evidence-based practice for the optimal use of simulation in health care. Without a systematic framework for guiding and structuring learning opportunities in simulation environments, improvements in performance may be limited and non-sustainable. Those involved in designing medical

training curricula need to work with scientists, clinicians and practitioners to ensure that contemporary technology is used effectively and efficiently to maximise the return on investment and promote improved patient safety and health care provision. Learning and simulation performance measures must be based on scientific evidence, account for individual and team-level performance differences, capture process and outcome measures, adhere to standards of reliability and validity, and address real or perceived barriers to measurement. In order to optimise the development of future generations of expert health care providers, advances in simulation technology need to be coupled with effective instructional systems design, with the latter being strongly guided by contemporary research from the learning and cognitive sciences.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Figure S1. An example of collecting process measures during medical simulation scenarios.

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