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A novel approach to minimize error in the medical domain: Cognitive neuroscientific insights into training*

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Abstract

Medical errors are an inevitable outcome of the human cognitive system working within the environment and demands of practicing medicine. Training can play a pivotal role in minimizing error, but the prevailing training is not as effective because it directly focuses on error reduction. Based on an understanding of cognitive architecture and how the brain processes information, a new approach is suggested: focusing training on error recovery. This entails specific training in error detection and error mitigation. Such training will not only enable better responses when errors occur, but it is also a more effective way to achieve error reduction. The suggested design for error recovery training is to begin with detecting errors in others. Starting off with highly visible and even exaggerated errors, and advancing to more challenging detections and finally requiring to detect errors within oneself rather than in others. The error mitigation training starts with providing the learners with the correct remedial actions (after they have detected the error). With training, the learners are required to select the appropriate actions within multiple choice alternatives, and eventually are required to generate the appropriate remedial responses themselves. These can be used for instruction as well as for assessment purposes. Time pressure, distractions, competitions and other elements are included so as to make the training more challenging and interactive.

Proper training is a challenge. Conveying information effectively and efficiently to the learner and making sure they acquire the needed skills is not an easy task. Nevertheless, short-term knowledge acquisition is the relatively easy part in training. More difficult is to teach in a way that the learners retain what they have learned in the long run, so that they remember and can recall it long after the training and assessments are all completed. Even more challenging is that learners need not only to acquire the information and remember it, but also use it and apply it in practice in order to achieve better performance and outcomes.

What we must understand is that meeting such challenges depends largely on the human cognitive system. It must be engaged correctly, on its own terms, making sure that training is 'brain friendly' (for details, see Dror in press (a)). If we do that, then the correct mental representations are formed and the information is much more likely to be learned quickly, remembered and used. Hence, success in training depends critically on it being guided by the human cognitive architecture and how the brain processes information. Such a cognitive neuroscientific approach to learning provides important insights into how best to design and deliver training (e.g. Dror et al. 2008; Cherrett et al. 2009; Pauker & Wong 2010).

Training to minimize error is very important in all domains, but has special importance in medicine. The problem is that training to minimize error is not simple. In contrast to many training subjects that simply entail specific information that needs to be learned, minimizing error involves not only conveying information. Minimizing error must derive from insights and understandings of the causes of error and human cognition.

This is clearly demonstrated by inadequate attempts to reduce error *via* policy measures. They are not as effective because they do not take into account the cognitive roots of error. In the United States, for example, Medicare and medical insurance companies have decided to stop paying for costs associated with error. If a patient needs a leg to be amputated, but ends up having both legs amputated because initially the wrong leg was removed, Medicare will only pay the cost of amputating one leg, and not the cost of both amputations. Similarly Medicare will not cover the costs of treating a variety of errors, e.g. 'when patients receive incompatible blood transfusions, develop infections after certain surgeries or must undergo a second operation to retrieve a sponge left behind from the first' (Sack 2008). Such policies may be justified for a number of reasons, but as measures to minimize error, they are misguided and ineffective. Nevertheless, this policy was intended to minimize error (Sack 2008).

More drastic, cognitively uninformed, policies aimed at reducing error include fining hospitals when errors occur. For example, Rhode Island State Department of Health fined a hospital for its third instance of operating on the wrong side of the brain (Goldstein 2007; Mello 2007), and the State of California fined nine hospitals for medical errors (Engel 2007).

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In fact, 'wrong-side surgery is a persistent problem in American healthcare' (Mello 2007), as well as in England, where 57 such errors occurred in 2009 alone (Yeoman 2010). The number of preventable medical errors that result in death is estimated to kill 44,000–98,000 people in the United States every year (Kohn et al. 2000), and the number of medical errors that occur but do not result in death is considerably higher.

It is critical to deal with errors through cognitively informed policies and actions, one of which is training – the topic of this article. Effectively dealing with errors requires a better understanding of their causes, and developing proper cognitively informed training to minimize them.

First, we need to consider and appreciate human cognition and the brain, and how they can lead to erroneous decision making in general, and specifically to medical error (Pauker & Wong 2010). These entail understanding perception, interpretation and judgements, all complex topics in how humans process information.

'Perception is far from perfection' (Dror 2005(b)). Humans do not passively and accurately perceive and interpret information from the environment. The brain has limited resources and cognitive processing capacity. Therefore, our cognitive system has developed a whole array of mechanisms that help deal with its limitations. Such cognitive mechanisms prioritize and filter information, paying selective attention to certain information while ignoring the rest. Other cognitive mechanisms entail using schemas, automaticity, chunking and heavy reliance on top-down information (Fraser-Mackenzie & Dror 2009; Dror in press (b)). All of these allow humans to operate efficiently and flexibly in complex environments, even though they have limited cognitive resources.

However, the very cognitive architecture and mechanisms that allow such remarkable performance also make the cognitive system prone to error. Examples of these would be motivated perception, tunnel vision and bias (Balcetis & Dunning 2006; Dror & Charlton 2006). Other contributors to error range from escalation of commitment and belief perseverance to group think and over confidence. Particularly important for clinical errors are, among others, biases in dealing with uncertainty. What is intriguing is that with expertise, with enhanced abilities and skills, such vulnerabilities to error increase (for details, see Dror in press (b)).

To better understand medical error (so that we can effectively and efficiently train to minimize it), it is essential to consider the cognitive system within the medical environment in which it operates. Given the complexity and variations in medical environments, I will only focus on three of those elements:

(1) *Time pressure*: Often decisions and actions are taken under time pressure and constraints (this is especially, but not only, notable in emergency medicine, see Croskerry et al. 2008). This means that the information available to the cognitive system is often limited (both in quantity and in quality). Furthermore, under time pressure information can only be evaluated and considered in a very limited way. Finally, the medical decision-making environment entails balancing risk and benefits, and time pressure affects risk taking (Dror et al. 1999). We also need to understand that the human brain has two distinct decision-making systems. The first is more analytic, rational, controllable and objective, whereas the second is more experiential, subjective and relatively independent of language, but is much faster (Payne et al. 1993; Sloman 1996; Fraser-Mackenzie & Dror in press). Therefore, under time pressure, the brain often engages and uses a different decision-making system, and it is therefore important to make sure to train the cognitive systems that will actually be used.

(2) *Information is piecemeal*: In the medical environment information is divided and scattered in many ways. First, there is a whole team of professionals dealing with a single patient, and cognition is distributed across a variety of people (Dror & Harnad 2008, for issues pertaining to distributed cognition). Second, shift changes in hospitals mean that every few hours there is a turnover of staff, and information needs to be relayed to a whole set of new care providers. Each of these issues can easily lead to error, and their combination is particularly error prone.

(3) *Technology*: Many medical errors can be minimized, if not eliminated by technological and system solutions. For example, electronic prescribing systems can tackle a huge source of medical errors (Bates et al. 1998; Kaushal et al. 2003). Indeed, such systems helped cut medication errors in half (Sack 2008), and have been recommended by the National Academy of Sciences report on Preventing Medication Errors (NAS 2007; recommendation 3). However, other technological medical instrumentations often ignore the human cognitive system and contribute to error (Dror 2007(a)). Take, for example, patient monitoring devices used in critical and intensive care units. They are designed with little to no consideration and understanding of human cognition and the medical environment, and therefore, many times result in negative effects (Donchin & Seagull 2002, Alameddine et al. 2009). For instance, they are set at such low thresholds, that they go off very often as false alarms, thereby causing them to be largely ignored (Lawless 1994). Using technology, and especially cognitive technology that complements and interacts with human experts, is a challenging endeavour and must be done correctly (Dror 2005(a)).

It is no surprise that in such an environment errors occur. Understanding how these and other elements in the medical environment influence cognition and can lead to error provides the framework for constructing training in this area.

The prevailing training to minimize error is focused on error reduction. Knowing the origins of errors enables to train for their reduction. For example, errors in drug administration emphasize the necessity to ensure that the right drug, at the right dosage, at the right time, is given to the right patient. Developing and training 'red rules' that 'must be followed to the letter' and behaviour norms such as Stop, Think, Act and

Review (STAR), are all methods to minimize error *via* error reduction (e.g. Riegelman 1991; Yates et al. 2004, 2005; Golnik & Palko 2006). It is hard to determine the efficiency of the existing approach to directly train in error reduction. It is clear that errors persist in the medical domain, but it is also clear that the medical environment and human cognition are a fertile ground for error.

Are there other important, perhaps better, ways to minimize and tackle error in the medical domain? And what insights can cognitive neuroscience provide to enhance training to minimize errors? A very different approach for training in minimizing error[1] is suggested – an approach that derives from cognitive neuroscience insights, and which provides a number of advantages over direct error reduction training.

The suggestion is that some training focuses on error recovery rather than on error reduction. The advantages of focusing on error recovery are not limited to providing the skills and knowledge needed to mitigate error and thereby minimizing the consequences of error. My view is that *training in error recovery is a cognitively more effective way to reduce error than training in error reduction.* Hence, I am not suggesting giving up on trying to reduce errors because they are unavoidable (given human cognition and the medical environment). Rather, I am suggesting a cognitively more effective way of reducing error.

Error recovery is important in critical care (Patel & Cohen 2008), as well as in many other medical settings, from medication administration to surgery. Indeed, expertise may be manifested in part in superior abilities to recover from error (Dror in press (b); Patel & Cohen 2008). Error recovery training, as will be argued below, will reduce error, as well as provide training for dealing with errors that have occurred. Let me explicate what error recovery training entails, and how to achieve it.

Error recovery requires training in both rapid error detection and in what to do to recover from it. Clearly, some errors are catastrophic and cannot be fixed; other errors allow some degree of mitigation of the consequences, whereas others can be totally remedied with proper and quick action. Training in error recovery can be best achieved through interactions with real scenarios. These can be orchestrated in simulations, videos and interactive videos, gaming and other educational tools that emphasize the active role of the learner (e.g. making videos interactive; Cherrett et al. 2009).

The first step in error recovery training is detection of errors. This can be achieved in a number of ways. As long as the learner is required to detect errors through interactive and experiential training, and gets feedback (positive and reinforcing when an error is detected, and informative when it is not), the training is in the right direction. The training will be more effective if the learning is challenging, starting with more obvious and salient errors. As the learner is improving in their detection ability, the training advances to more and more subtle and harder to detect errors. The initial detection training may even need to exaggerate and over emphasize the errors (Dror et al. 2008). It is important to include in error recovery training a whole range of possible medical errors, such as slips and mistakes, in evaluation and in execution (see cognitive taxonomy of medical errors; Zhang et al. 2004).

The ultimate goal is to train medical professionals to detect their own errors. But it is always easier to see errors in others than in oneself. Furthermore, misattribution theory suggests that people are more open and accepting of errors when they are committed by others, and we focus more on observed behaviour in others, while we see ourselves mainly in the context of motivations and other mental processes (Pronin et al. 2002). Hence, the recommendation is for training to begin with teaching to detect errors committed by others. A second and more advanced stage of training should shift to teach and emphasize self-error detection, that is, to train the learners to detect their own errors. To induce error, one has to use clever training designs, such as sabotage. Continuing to make the training challenging to the learner is very important. In addition to making detection more difficult, other challenges should be created, for example, how quickly an error is detected, adding distractions, or competition among learners.

Teaching to detect error is very critical, but it is only the first phase in error recovery. Once an error has been detected, recovery countermeasures need to be taken as soon as possible to remedy, or at least mitigate, the error. Teaching these, again, must be taught in increasingly complex and challenging conditions. First, when the learners detect an error, they are provided with the appropriate protocols that are most suitable for recovery. Then, at the next stage, rather than providing the recovery actions, the learners will be presented with a list of possible actions and they need to select the appropriate actions and their correct sequence. Finally, as the learners progress, they have to generate the recovery actions themselves. More advanced training may incorporate more and more complex scenarios, as well as time pressure and distractions. All the techniques above (for both error detection and recovery actions) can be used for training and for assessment purposes, and debriefing is very important to maximize benefit.

Error recovery training does not end with error detection and remedial actions. Perhaps the most critical element in error recovery training is learning for future praxis. With enhanced ability to detect error, and dealing with and experiencing its consequences first hand, the learner's cognitive systems are effectively being tuned and sensitized to errors. For example, being operationally aware and conscious of the possibilities for error to occur, automatically allocating cognitive resources to error prone situations and so forth. Error recovery training is more effective in achieving these than the prevailing direct error reduction training that instructs the learners to pay attention, to remember and to be aware.

The point is that direct error reduction training alone is less cognitively and brain-friendly than indirectly reducing error *via* training that focuses on error recovery supplemented by error reduction training. It is the error recovery training that will create more salient and long lasting mental representations, and will better configure the cognitive system in terms of attention allocation, all of which will work effectively towards error reduction (Dror in press (a)). Furthermore, error recovery training has the advantage of also giving knowledge and skills that are critical if and when an error does occur.

The medical domain has a unique set of challenges in training. However, if we remember that the learner is our focus, and training needs to make sure that they not only acquire the information, but also remember and use it; and we use cognitive neuroscience insights to help design and deliver more brain friendly learning, then we can considerably advance medical training for the benefit of patient care. Furthermore, there is much that medical training can learn from other professional domains (such as aviation and policing), where professionals need to make quick assessments, weigh risk and determine the best course of action (Dror 2007(b)).

Medical errors many times derive from team-level distributed cognition and the systems in place (as noted earlier in this article). Hence, training in error recovery should also address the team and system level. The individuals, as well as the technology, are the building blocks, but patient care and error are issues of cognitive systems, which can be improved by training individuals, their collaborative performance and distributed cognition (Reason 1990; Dror & Harnad 2008).

Training is only one component in minimizing error. Many cognitive errors can be countermeasured by system design aimed at reducing complexity (Strong 1999) or by proper colour coding, size or shape differentiation and the elimination of names (as in drugs) that sound alike (Nolan 2000). The focus of this article is on training, and suggests that minimizing errors, both in terms of reduction of their occurrence in the first place, and effectively dealing with them when they do occur will be achieved by focusing training on error recovery together with error reduction training.

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Note

1. My suggestion is not to substitute the existing training in error reduction but to complement it with a different approach.

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