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# A cognitive perspective on technology enhanced learning in medical training: Great opportunities, pitfalls and challenges

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## Abstract

As new technology becomes available and is used for educational purposes, educators often take existing training and simply transcribe it into the new technological medium. However, when technology drives e-learning rather than the learner and the learning, and when it uses designs and approaches that were not originally built for e-learning, then often technology does not enhance the learning (it may even be detrimental to it). The success of e-learning depends on it being 'brain friendly', on engaging the learners from an understanding of how the cognitive system works. This enables educators to optimize learning by achieving correct mental representations that will be remembered and applied in practice. Such technology enhanced learning (TEL) involves developing and using novel approaches grounded in cognitive neuroscience; for example, gaming and simulations that distort realism rather than emphasizing visual fidelity and realism, making videos interactive, training for 'error recovery' rather than for 'error reduction', and a whole range of practical ways that result in effective TEL. These are a result of e-learning that is built to fit and support the cognitive system, and therefore optimize the learning.



E-learning is frequently used in many aspects of medical training. The reliance on technology is getting more and more common, and the future seems to hold an ever increasing use of e-learning in medical training. However, we need to ask ourselves: How is such technology used? Does it really enhance learning? What makes e-learning work?

Too often e-learning merely means transcribing from one medium to another. For example, making lectures available as podcasts, putting learning materials on the internet, or making an e-learning module out of a PowerPoint presentation. On the face of it there is nothing wrong with this. Indeed, such e-learning enables learners to easily access the training, and to learn remotely at their own pace, whenever and wherever is most convenient for them. However, such e-learning, characterized as predominantly transcribing from one medium to another, does not really take full advantage of the opportunities that technology offers (Dror 2008).

Many times e-learning not only fails to enhance learning, but can be detrimental to the learning experience and outcomes. This should not be much of a surprise given that various forms of e-learning were not originally designed or packaged for technological use. For instance, podcasts are for the most part lectures that were delivered to students, and their structure, content, illustrations, interactions, and their entire conception was geared toward a face-to-face presentation. Therefore, their transcription into a podcast is far from ideal. Indeed, podcasts should be presentations that are totally constructed for this medium, with appropriate design, delivery, examples, etc., all specifically effective for podcast presentation, in contrast to a face-to-face presentation. Similarly, other e-learning that is a mere transcription from another medium, is not built to optimize and take advantage of the technology. It is in fact based on and built to fit another medium, and its transcription may degrade its

## Practice points

- E-learning should be used to make training more cognitively effective.
- Transcribing learning from one medium to the other is full of pitfalls.
- Cognitive load can be controlled by minimizing the amount of information (the quantitative approach) or by packaging the information in a more brain friendly fashion (the qualitative approach).
- Technology enhanced learning enables to engage and work more effectively with the cognitive system, by providing appropriate interactions, involvement, participation, and challenges to the learners.
- Simulations and other e-learning tools should not focus on realism and visual fidelity, but on making sure that the learners acquire optimal mental representations that they will remember and use in practice.
- Making videos interactive is a relatively simple way of enhancing the effectiveness of training.

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effectiveness (for sure it does not optimize and fulfill the potential that technology offers).

E-learning is too often driven by the technology and not the learner and the learning. As new technology becomes available and is used for educational purposes, educators often take existing training and simply transcribe it into the new technological medium. This puts the technology at the forefront, driving the learning, rather than being subservient to it. Technology is there to serve the learner and the learning. Therefore, one needs to think of the learning outcomes, and only then consider if to use technology at all, and if technology can be useful, then what technology and how best to use it.

Making technology enhanced learning (TEL) effective, rather than e-learning that merely transcribes from another medium, requires a change in focus. *It is not what you teach or what technology you use that counts, the focus must be on what the students learn.* What knowledge and skills the learners acquire, and not only acquire, but what they will remember in the long term and apply to their practice. Many times technology can be a very powerful tool in achieving these learning outcomes, but only if it is used correctly. The many wonderful and exciting opportunities that technology offers are also full of pitfalls. To respond to these challenges, technology must be brain friendly (Dror 2011c).

TEL must support the cognitive architecture of the learners, by, for example, providing appropriate mental representations and correctly considering cognitive load, as will be illustrated below. Too much attention and effort is placed on visual fidelity and realism in training videos, gaming, and simulations, rather than on their cognitive effectiveness. In fact, videos, gaming, and simulations can be more effective when they intentionally distort certain elements in a way that enhances the learning outcomes.

Learning should make things as easy as possible, designing and delivering educational content from an understanding of how the cognitive system works. If you look at Figure 1 (a), it is relatively demanding to spot 'the odd one', whereas it is relatively easy to spot the 'odd one' in Figure 1(b). The only difference is that in Figure 1(a) the transition from black to white is a threshold all at once, whereas in Figure 1(b) it is gradual. However, this seemingly simple and technical change has important and meaningful implications for how the brain processes this information, causing a 'pop out' effect in the right panel (Kleffner & Ramachandran 1992). The presentation in Figure 1(b) does not require as many cognitive resources and is not as taxing to process as Figure 1(a). This is very important as the cognitive system has limited resources, and by presenting information correctly, cognitive load is reduced, freeing and optimizing resources, and hence enhancing the learning.

The example above illustrates that to deal with cognitive load issues you do not necessarily need to reduce the amount of information (a quantitative approach); if you package the information more effectively from a cognitive perspective (a qualitative approach), then you reduce the cognitive load without reducing the amount of information conveyed to the learner.

The aim is to take the burden off of the learner, and have the experts who design the learning make it their job to assist and support the learners from a cognitive perspective. This goes beyond the classical approach of instructional design; those who develop such concepts must be trained in 'brain friendly and cognitively sound learning design'.

This cognitively informed approach may even require distorting and manipulating the learning materials so that they exaggerate and over emphasize the important information that the learners need to acquire, remember, and use. For example, see Figure 2, where the learning materials (in this case aircraft) can be distorted and manipulated to enhance learning by exaggerating the distinctiveness and uniqueness of each

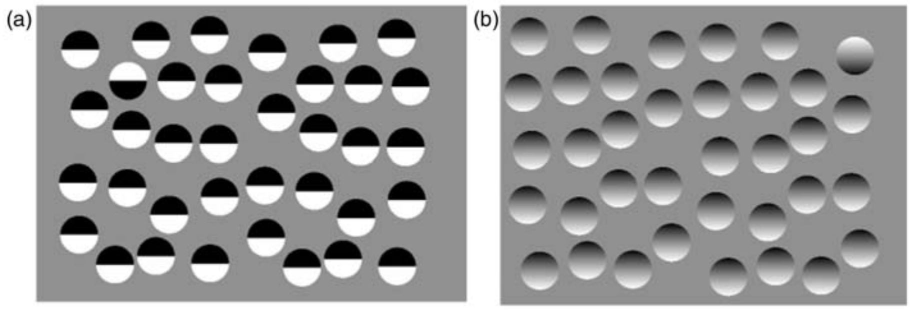


**Figure 1.** Finding the 'odd one out' in (b) is easier than in (a). By understanding the cognitive system, one can optimize learning materials and enhance learning.

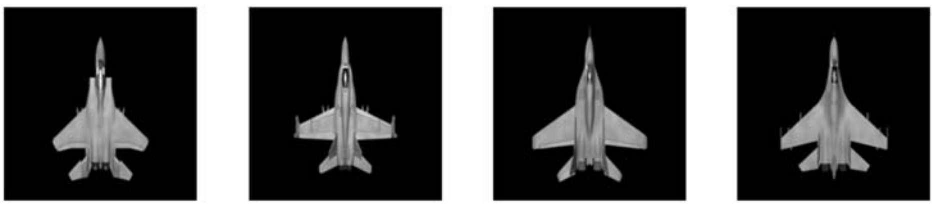

**Figure 2.** By distorting the learning material to artificially exaggerate the critical information (i.e., the distinctive and unique features of each aircraft in the example above), learning is made more effective.

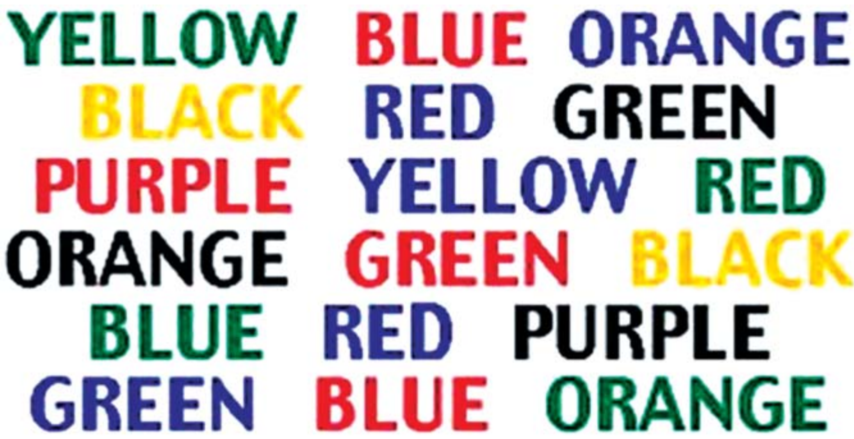


**Figure 3.** Because of how the cognitive system works, it is very hard to just name the ink colors (without reading the words). Understanding how the cognitive system processes information is critical for learning.



aircraft. By doing this, the learners do not spend cognitive resources figuring out these distinct features (that are the important information needed to identify the aircraft), but can focus on actually learning them. Experimental studies have shown how such learning materials need to be designed, and empirically demonstrated their effectiveness in enhancing learning (Dror et al. 2008).

The suggested approach is to design and deliver training through a deep appreciation and understanding of the learners' cognitive system. Taking into account and being guided by the architecture of the cognitive system. Knowing, for example, how the brain perceives information, how the learners interact with the learning materials, how information is processed and encoded by the learners, are the building blocks and foundation of learning.

When we consider how to use technology to enhance learning in general, and in medical training specifically, we need to think if and how it can help to better engage the cognitive system. A final illustration to this approach is presented in Figure 3. If you try to name the ink colors (not read the words) in Figure 3, you will notice that although this task is clear and simple, it is very hard to do and requires a great deal of effort (MacLeod 1991).

It is beyond the scope of this article to explicate the cognitive architecture in detail and the profound implications this has on designing and delivering effective training (Dror 2011a). However, we needed to make the basic, but critical, point that cognition and learning – not the technology itself – must be the guiding and driving force in enhancing training. Now the question is if, and how, technology can assist in this task in general, and specifically within medical training.

In medical training it is especially important that the learners apply and use in practice what they have learned. An effective way of achieving this is through challenging interactions that requires the learners to take an active role in the training and learning experience. Technology can be a great tool in achieving this kind of training. As more sophisticated technology is available, new opportunities will arise. However, we must always remember that the technology is subservient to the learning, and is there to enhance the learning. Below we discuss three ways in which technology can enhance learning in the medical domain: interactive videos, gaming, and simulations.

Videos are widely used in the medical domain. They enable the capture of important learning opportunities that may not present themselves during clinical cases. However, videos are not cognitively friendly on their own. The learners view them passively, and the elaboration on key learning outcomes does not take place at the most appropriate time; i.e. when the relevant information is presented in the video. Making videos interactive engages the learners and actively involves them with the material presented in the video, so they pay attention and focus on the learning. The interactions in the video are intended to challenge the viewers and make them cognitively effective. For example, the viewers are required to point to certain objects, detect errors, and answer multiple choice questions.

As the learners go through the video they get immediate feedback and points for their performance, and their scores (absolute scores or/and relative to others) are presented on the screen. Interactive videos, when designed properly, are very cognitively effective. We assessed the effectiveness of an interactive video that we developed for training in health and safety in a laser laboratory. We randomly assign learners to three learning condition groups, followed by a test. Those who viewed the passive video alone scored 40.83% on the test that followed, those who viewed the passive video along with a face-to-face lecture scored 64.44% in the test that followed, and those who used the interactive video scored 73.22% on the test that followed.

Making videos interactive requires technical skills and cognitive knowledge. The technical skills are minimal, using standard software (such as Adobe Premiere, Flash and Photoshop) it is relatively easily to create the interactions. The cognitive knowledge is required to determine what interactions are best to include, and when, so as to maximize the learning (Cherrett at al. 2009; Dror 2011b).

We have recently developed an interactive video on intraoperative radiation (Figure 4). The aim was to teach about radiation hazards and how to avoid them, and how to

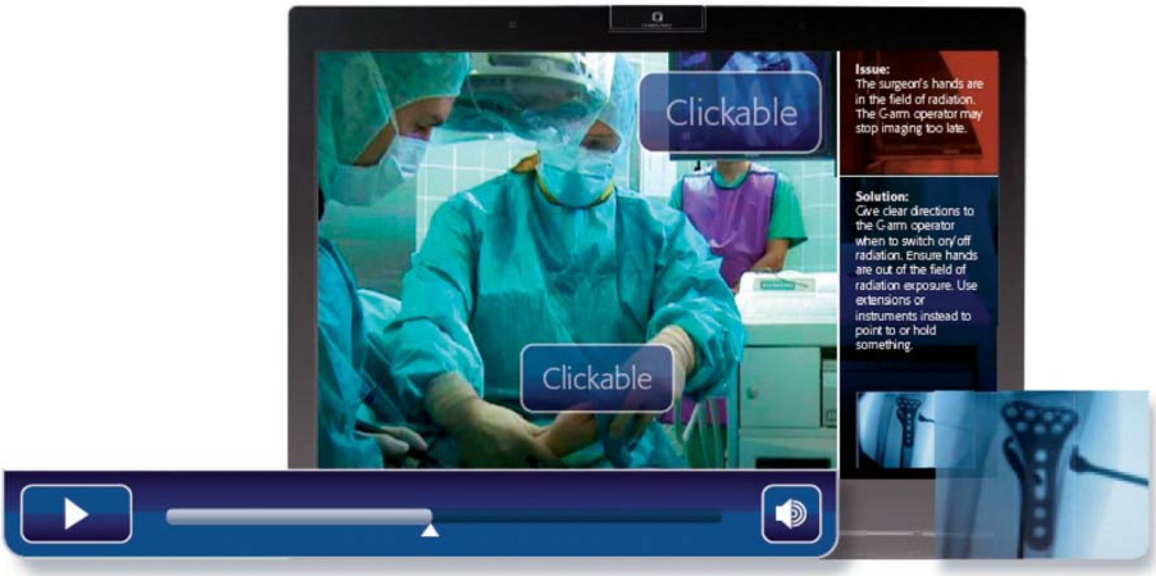


**Figure 4.** An interactive video requiring the viewers to detect typical errors and provide answers to questions presented during the video. This video can be viewed interactively at: www.cci-hq.com/index.php?sub=interactive (and follow the 'medical surgery' link).

achieve optimal working space and best possible images when using a C-arm. The interactive video included clips of simulated clinical work involving fixation of a proximal femur and a distal radius fracture. It included 15 typical errors, and required viewers to spot the errors and give answers to questions throughout the video.

Medical training is particularly well suited for TEL. In particular, gaming can capture many important elements that are critical for cognitively efficient learning that is applicable to medical practice. One such element is time pressure and distractions. Often medical procedures are performed under less than ideal conditions. If training is aimed to be applied in practice, it is important to properly set the training so the applicable information is well acquired and is better remembered (e.g. Smith & Vela 2001). This entails adding elements of time pressure, different types of distractions, and context.

Gaming also allows for training beyond the individual level. The medical context often involves distributed cognition across team members, who need to work in coordination (Dror & Harnad 2008). Multiple player games are a good platform for providing such training. Another element in which gaming can be an efficient technological tool is in training how to cope with unexpected events. Medical practice involves unexpected events, and the ability to quickly and efficiently deal with them is paramount for patient safety. Gaming provides good opportunities for training in these types of scenarios.

The use of gaming in the medical domain allows for training on important issues, but to do so within a challenging and effective learning environment. Gaming engages the users; they get involved and take an active participating role in the game. If constructed properly, the users enjoy using this educational tool and play it recreationally. Games can be a very effective tool for medical training, enhancing learning considerably. However, gaming can be too much fun, causing the learning to be side stepped and forgotten. As with all e-learning, the learners and learning is the focus, rather than the technology. The cognitively guided gaming tools allow to properly and effectively embed the learning within the fun and engaging game.

Medical simulations, virtual patients, are vital tools in medical training. Patients in real practice do not always present the best training examples, and even when good learning examples are presented by real patients, patient care is the main focus and objective. Training in the clinical environment therefore takes a secondary role and is pursued only as much as it does not hamper patient safety and care. Medical simulations allow for the selection of the most effective clinical cases and for learning-centric training. Simulations also allow students to explore, test actions, and observe their effects (Schank & Farrel 1988; Miller et al. 1999), which is important for learning but would be inappropriate on real patients.

Furthermore, simulations allow the users to 'restart' and 'reset', so the learners can start all over, providing learning experiences that are unattainable with real patients. For example, understanding how to manage a critical patient whose airway is severely compromised and requires a cricothyrotomy is essential to the safety of the patient; such scenarios, which may not often be encountered in everyday practice, can be presented many times with nuances that allow the learner to better recognize patterns and perform the necessary interventions. Errors and mistakes will happen, but in simulations they do not have fatal consequences and can even be induced to provide powerful and memorable learning (Dror 2011b).

Medical simulations, as well as interactive videos and gaming, are learning technologies that can be especially effective in training if they artificially exaggerate and make salient the critical learning knowledge (Dror et al. 2008).

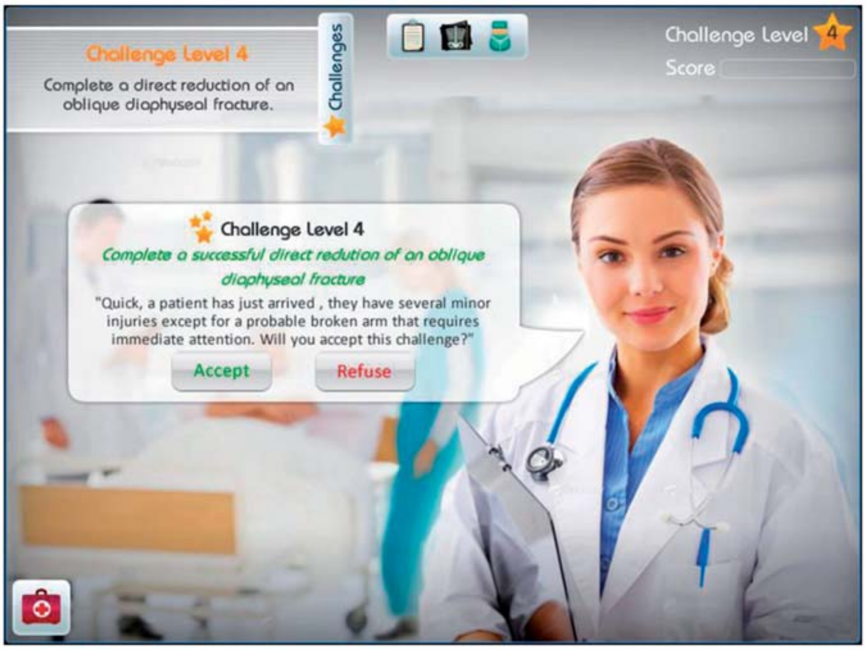


**Figure 5.** Gaming can be a very effective tool for training in the medical domain. It allows, among other things, to train for effective coordination and distributed cognition among team members, coping with time pressure, distractions, and unexpected events. However, if the gaming is not cognitively effective in embedding the training within the game, the fun and entertainment can minimize the learning rather than enhance it.

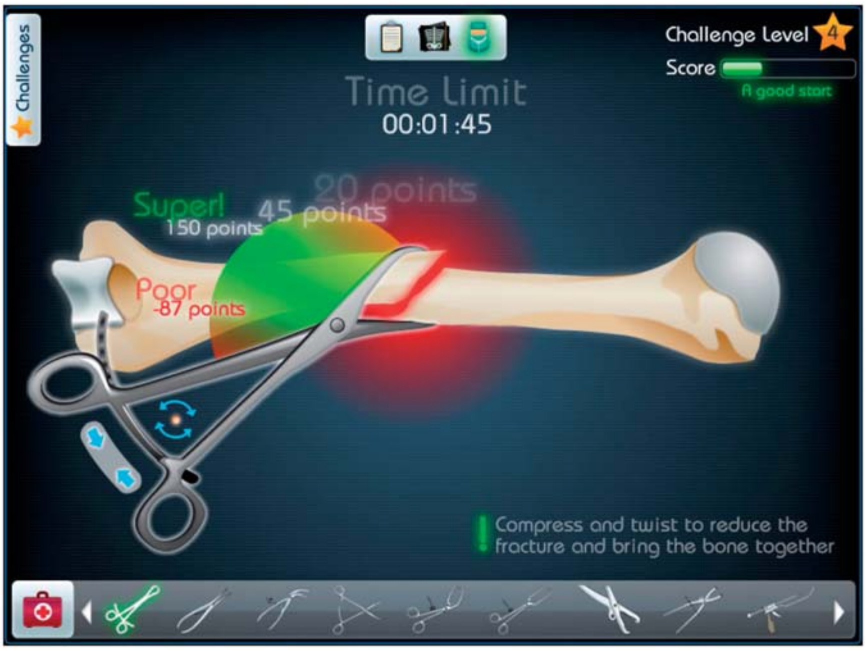


**Figure 6.** Gaming and simulations allow learners to explore different actions and their consequences, and to learn through a variety of experiences provided by 'restarting' multiple times.

This entails distorting the realism, but medical simulations often promote themselves as being 'realistic', providing 'real life experience', etc (similarly, gaming often emphasizes visual fidelity). However, from a cognitive perspective, such things may not be needed for effective training. Sometimes, the visually distorted, less realism and visual fidelity, provide better and more enhanced learning.

The distortions, when cognitively guided, provide an opportunity to guide the cognitive system, to reduce cognitive load, to help provide effective mental representations, and to optimize cognitive resources and attention. Such technologies also offer opportunities to provide accurate assessment of abilities and skills; they allow, for example, to vary the saliency of error and to test what level is needed for identification (as greater saliency is required, the lower the assessment score; if students are able to perform well as salience is decreased, higher scores are provided).

The cognitive perspective in developing and using such e-learning ensures that the technology indeed enhances the learning. It is important to also consider how such technology can make sure the learning is appropriately generalized and transferred to medical practice (Son & Goldstone 2011). The use of e-learning offers great opportunities for such transfer of knowledge, as it enables the coupling between activity and the environment, which plays an important role in forming transferable knowledge that is useful and flexible (Brooks 1991;Winn 2003). E-learning can provide dynamic scaffolding (Wood et al. 1976), in which technology provides assistance to the learners, as and when needed. As learning progresses, the learners require less assistance, and can deal with more complex scenarios (Aleven & Koedinger 2002; Dror 2011b). Such dynamic scaffolding requires diagnosis, calibration, and fading (Puntambekar & Hübscher 2005), which e-learning is well suited for.

The medical domain can benefit much from e-learning. It is particularly suited for TEL, but only if the technology is correctly harnessed to support and advance the learning outcomes. This requires the use of technology as a tool that enables more cognitively effective training. This can take place by exploiting opportunities that technology offers to further expand and implement existing approaches to learning, such as use of scaffolding, minimize cognitive load, optimize mental representations, etc.

A cognitive approach to e-learning can also bring about new approaches to learning, and open up new possibilities for improving patient safety and care (such as training for error recovery, see Dror 2011b). Such new directions are needed, as much of the current attempts to reduce preventable patient harm have been shown to have little effect (Landrigan et al. 2010). TEL is critical for medical training, but it is also full of potential pitfalls. A cognitive perspective is critical if we want to live up to the opportunities and challenges that technology offers us in medical training (Dror 2008).

***Declaration of interest:*** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

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LANTY O'CONNOR is the Manager of Simulation Technologies in the Department of Simulation Technology and Immersive Learning at Feinberg School of Medicine, Northwestern University. He directs the work of two distinct teams: 1. an operations team composed of simulation specialists charged with carrying out immersive learning events; 2. an innovations team composed of engineers, artists, computer programmers, and research technicians charged with researching, developing, and implementing novel educational devices. Lanty has a particular interest in team dynamics/group learning and has worked with groups varying in composition from medical students and residents to professional athletes. Lanty is also the Co-Director of Medical Education for the Chicago Marathon.

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