Chapter 7
Enhanced Reality for Healthcare Simulation

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Abstract  Enhanced reality for immersive simulation (e-REAL®) is the merging of real and virtual worlds: a mixed reality environment for hybrid simulation where physical and digital objects co-exist and interact in real time, in a real place and not within a headset. The first part of this chapter discusses e-REAL: an advanced simulation within a multisensory scenario, based on challenging situations developed by visual storytelling techniques. The e-REAL immersive setting is fully interactive with both 2D and 3D visualizations, avatars, electronically writable surfaces and more: people can take notes, cluster key-concepts or fill questionnaires directly on the projected surfaces. The second part of this chapter summarizes an experiential coursework focused on learning and improving teamwork and event management during simulated obstetrical cases. Effective team management during a crisis is a core element of expert practice: for this purpose, e-REAL reproduces a variety of
different emergent situations, enabling learners to interact with multimedia scenarios and practice using a mnemonic called Name-Claim-Aim. Learners rapidly cycle between deliberate practice and direct feedback within a simulation scenario until mastery is achieved. Early findings show that interactive immersive visualization allows for better neural processes related to learning and behavior change.

**Keywords** Enhanced reality · Virtual · Augmented and mixed reality · Virtual worlds · Hybrid simulation · Teamwork · Mnemonics · Name-Claim-Aim

### 7.1 Enhanced Reality

Enhanced reality for immersive simulation (e-REAL®) is the merging of real and virtual worlds: a mixed reality (MR) environment for hybrid simulation where physical and digital objects (VR) co-exist and are available for tactile interaction, in a real learning setting—and not within a headset [67, 69]. e-REAL integrates tools and objects from the real world onto one or more walls, embedded with proximity sensors enabling tactile or vocal interaction with the virtual objects.

Examples of physical objects include:

- Ultrasound and sonography simulators
- Pulmonary ventilators
- Defibrillators.

Examples of digital objects include:

- Realistic avatars and medical imagery (Fig. 7.1)
- Human organs and systems (Figs. 7.2 and 7.3)
- Overlay of electronic information and images onto projected surfaces (Figs. 7.3, 7.4 and 7.5).

Figure 7.1 illustrates a real medical tool operated on a patient simulator by learners who are in a dialogue with an avatar (that is, the virtualized colleague displayed on the wall), with medical imagery displayed both on a monitor and the walls.

Figures 7.2, 7.3 and 7.4 illustrate 2D, 2.5D and 3D images visible without special glasses, which can be manipulated by the hands without special joysticks (active pens). Learners are able through hand gestures to virtually take notes, highlight, erase, zoom inside/outside or rotate virtual organs and other displayed objects 360°, to cluster concepts by grouping them within boxes or by uploading additional medical imagery to gain a better understanding about what they are analyzing, to take screenshots and share them, to complete questionnaires, etc.

Figure 7.5 exemplifies the mirroring of a perioperative environment which can be overlaid with digital computer-generated information pertaining to a simulated patient, ultrasound images, ECG tracks, outputs from medical exams. The overlay of information is to enhance the user experience.
In a nutshell, the e-REAL system enables a multilayer vision: the many levels of the situation are made available simultaneously, by overlaying multisource info—e.g. words, numbers, images, etc.—as within an augmented reality display, but without needing to wear special glasses. By visualizing relations between topics, contextual factors, cognitive maps and dynamic cognitive aids, e-REAL improves the learners’ cognitive retention [29, 30, 33, 63, 65].

7.2 Enhanced Hybrid Simulation in a Mixed Reality Setting, Both Face-to-Face and in Telepresence

e-REAL is a synthesis of virtual reality (VR) and augmented reality (AR) within a real setting, a one of a kind mixed reality (MR) solution based on immersive interaction. In a nutshell, AR alters one’s ongoing perception of a real-world environment, whereas VR replaces (usually in a complete way) the user’s real-world environment with a simulated one.
VR is a communication medium that makes virtual experiences feel highly realistic. The term ‘virtual reality’ has been widely used and often creatively exaggerated by Hollywood producers and science-fiction writers for decades. Consequently, there are many misconceptions and expectations about the nature of the technology [5]. We define ‘virtual reality’ as synthetic sensory information that leads to the perception of environments and their content as if they were not synthetic [11]. Since the 1960s, VR has been used by the military and medicine for training and simulations, but it has also become fertile ground to evaluate social and psychological dynamics in academic settings [4]. For example, journalists use virtual reality to situate their readers within stories, educators use virtual technologies for experiential learning, and psychiatrists leverage virtual reality to mitigate the negative effects of psychological traumas [46].

AR is a general term applied to a variety of display technologies capable of overlaying or combining alphanumeric, symbolic, or graphical information with a user’s view of the real world [4]. We define ‘AR’ as an interactive experience of a real-world environment where the objects that reside in the real-world are augmented by computer-generated perceptual information—sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory. Overlaid sensory information can be constructive (i.e. additive to the natural environment) or destructive (i.e. masking of the natural environment) and is seamlessly interwoven
with the physical world such that it is perceived as an immersive aspect of the real environment [61].

MR takes place not only in the physical world or in the virtual world, but is a mix of the real and the virtual [23, 49]. We define ‘mixed reality’, as a hybrid reality, in other words the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time. There are many mixed-reality applications to help students learn through the interaction with virtual objects. For example, teachers can instruct students remotely by using 3D projections within a head-mounted display.

In e-REAL digital and physical objects co-exist in the real world, not within a headset, making e-REAL currently unique. e-REAL, as a MR environment for hybrid simulation, can be a stand-alone solution or even networked between multiple places, linked by a special videoconferencing system optimized to process operations with minimal delay (technically: low latency). This connectivity allows not only virtual objects sharing (like medical imagery, infographics, etc.) in real time, but also remote cooperation by co-sketching and co-writing (Fig. 7.6).
Fig. 7.4  Courtesy of the Center for Medical Simulation in Boston (MA, USA): overlay of information manually added on the e-REAL wall using a tracking system that allows for electronic writing, due to proximity sensors tracking the nails of the writer

e-REAL is a futuristic solution, designed to be “glocal” [64], “liquid” [7], “networked” [16] and “polycentric” [80], as well as virtually augmented, mixed, digitalized and hyper-realistic [67]. The key-words characterizing the main drivers that guided the design of this solution, and that are leading the further developments, include:

- **Digital mindset**, that is not merely the ability to use technology but is a set of attitudes and behaviors that enable people and organizations to foresee possibilities related to social media, big data, mobility, cloud, artificial intelligence, and robotics.
- **Visual thinking**, that according to Rudolph Arnheim implies that all thinking—not just thinking related to art—is basically perceptual in nature, and that the dichotomy between seeing and thinking, or perceiving and reasoning, is misleading.
- **Computer vision**, an interdisciplinary scientific field that deals with how computers can gain high-level understanding from digital images or videos; from the perspective of engineering, it seeks to understand and automate tasks completed by the human visual system.
- **Advanced simulation** that is a highly realistic imitation of a real-world object, process or system.
- **Multimedia communication** that is a system of relaying information or entertainment that includes many different forms of communication: for example, it might include video, audio clips, and still photographs.
Immersive and interactive learning, that encourages students to learn by doing and allows learners to cross conceptual and theoretical boundaries with the help of simulation or game based tools. It is one of the most promising methods in the history of learning by immersing the students or professionals in an interactive learning environment in order to teach them a particular skill or technique [3, 67].

Augmented and virtual reality within a hybrid environment, that allows learners to experience abstract concepts in three-dimensional space, transforming the passive learning into technology-assisted immersive learning.

Human and artificial intelligence cooperation, that does not require sheer computational power, but relies on intuition, and pre-evolved dispositions toward cooperation, common-sense mechanisms which are very challenging to encode in machines.

Cognitive psychology and neurosciences, that are different domains overlapping in the area of the neural substrates of mental processes and their behavioral manifestations.
Fig. 7.6 e-REAL Multimedia Design Labs at Fondazione Piazza dei Mestieri in Turin (Italy): Interactive teleconferencing system enhanced with the speech analysis app developed by Centro Studi Logos jointly with the Tiny Bull Studios and the Polytechnic School of Turin (Italy)

- **Anthropology and sociology of culture**, whose viewpoints are inspired by observing cross-cultural differences in social institutions, cultural beliefs and communication styles.
- **Hermeneutics** that refers to the interpretation of a given text, speech, or symbolic expression such as art. It also fosters a multi-layer approached by opening the meta-level related to the conditions under which such interpretation is possible. Consequently, hermeneutics foster learners’ metacognition by activating thinking about thinking and knowing about knowing, which contributes to higher-order thinking skills.
- **Narratology** that is the study of narrative strategies and structures as well as the ways that these affect human perception.
- **Design thinking applied to andragogy and pedagogy** that revolves around a deep interest in developing an understanding of the learners for whom educational content is designed—for example, questioning and re-framing problems in learner-centric ways, questioning assumptions and implications, helping to develop empathy with the target users.
- **Epistemology** that is the study of knowledge, justification and the rationality of belief which addresses such questions as: What makes beliefs justified? What does it mean to say that we know something? And fundamentally: How do we know that we know?
All these domains in our opinion must be related with a systemic and interdisciplinary approach: the one that is at the core of the research guidelines developed by Centro Studi Logos in Turin (Italy) since 1996.

### 7.3 e-REAL as a CAVE-Like Environment Enhanced by Augmented Reality and Interaction Tools

e-REAL uses ultra-short throw projectors and touch-tracking cameras to turn blank walls and empty spaces into immersive and interactive environments. It is designed as an easy, user-centered and cost-effective solution to the old CAVE environments, which are too rigid, difficult to be managed, and expensive.

CAVE—computer-assisted virtual environment—is an immersive VR and AR environment where projectors are directed to between three and six of the walls of a room-sized cube; usually the image projections change as the user walks around and moves his or her head. The name is also a reference to the allegory of the Cave in Plato’s Republic, in which a philosopher contemplates perception, reality and illusion [4, 20]. As shown in Fig. 7.7, these systems come in a variety of geometries and sizes, including rear-projection or flat panel-based displays, single and multi-projector hemispherical surfaces, each typically displaying field sequential stereo imagery. Most are designed to accommodate multiple users, each of whom wear LCD shutter glasses controlled by a timing signal that alternately blocks left- and right-eye views in synchronization with the display’s refresh rate. Most systems incorporate some method of tracking the position and orientation of the lead user’s head to account for movement and to adjust the viewpoints accordingly. In such multi user scenarios, all other participants experience the simulations in 3D, but passively.

There are a number of critical reasons to develop e-REAL as an alternative to the CAVE for immersive simulation in education and training. Allowing users to work...
without special glasses is an important reason. Avoiding joysticks or other devices (usually haptic gloves) in order to interact with the visual content is another reason. Other reasons include a higher degree of realism and the opportunity to have all the users, and not only one person at a time, interact with the content.

e-REAL is an innovative solution, it is very easy to use and 10–12 times less expensive than a CAVE. With both permanent or portable fixtures, it is so simple that two buttons are enough to manage it all—from a control room or remotely by the Team Viewer™ software, without the need for 3D glasses or joy-sticks to interact with the virtual objects (see Figs. 7.8 and 7.9).

e-REAL offers a unique user experience, a combination of visual communication and direct interaction with the content—by gesture or spoken commands—immersing people in an entirely interactive ecosystem. Figures 7.10, 7.11, 7.12, 7.13, 7.14, 7.15, 7.16, 7.17, 7.18 and 7.19 provide a visual explanation about the main features of the system.

Each e-REAL lab comes packed with a starter kit that enables countless activities using simple gesture and spoken commands. A number of apps and contents are available off-the-shelf, and many others can be quickly tailored. Each e-REAL can be customized with a number of multimedia contents and MR tools:

- Multimedia libraries;
- Interactive tutorials;
- Holographic visualizations;
- Real-time and live holograms;
- Podcasts and apps;
Fig. 7.9 Courtesy of Centro Studi Logos, Turin (Italy), Logos Knowledge Network, Lugano (Switzerland), LKN, Berlin (Germany), Logosnet (Houston, TX, USA). Representative e-REAL permanent installation: (1) a regular control room, (2) a briefing and debriefing room with an entire common wall transformed into a large electronic and interactive whiteboard, which allows avoiding a regular projection or a standardized electronic whiteboard, (3) the immersive and interactive room for both the simulation and a first rapid onsite debriefing—enriched by the contextual factors displayed on the walls. This setting is also very useful for simulations that can be enhanced by pausing and adding further visualizations and notes

- Task (or skill) trainers, healthcare tools, wearable devices such as glasses, headsets, watches and gloves.

Summarizing, the main technical features are:

- VR and AR that happens in the real world (MR for hybrid simulation) using 2D-2.5D-3D projections on the walls, not within special glasses;
- Visualization is interactive, immersive and often augmented;
- Speech recognition may be part of the adventure as well;
- Users do not require special glasses, gloves, head-mounted displays, etc.;
- It is very easy to use: only two buttons are needed (one to start and stop the server, and another from a remote controller, to switch on and off the projectors);
- A number of pre-loaded scenarios are available;
- It is easy to import and show existing content (images, videos);
- It is easy to create and edit new content, with tailored multimedia editors;
- Both permanent and portable fixtures are available.

The following link provides a more detailed description of the settings and the available tools:
Fig. 7.10 Courtesy of the Red Cross of Italy in Bologna (Italy). e-REAL representative setting based on a multimedia animated visual storytelling made interactive by touch sensors tracking fingers or by vocal commands. Ultra-short throw projectors are working on common walls (level 4 or 5 finish) transformed into a maxi and touchable screen by the proximity sensors

https://www.youtube.com/watch?v=RZn3fdZNp3w&feature=youtu.be (courtesy of the Center for Medical Simulation in Boston, MA, USA, and the Polytechnic School of Milan, Italy).

7.4 The Simulation’s Phases Enhanced by e-REAL and the Main Tools Made Available by the System

1. Briefing and debriefing phases

Briefing and debriefing phases are strongly enhanced by e-REAL, by facilitation of cooperative learning and systems thinking fostered by dynamic visualization—an approach aimed at building a shared understanding of the non-linear behavior of complex systems (e.g. communication within a working team, car crashes, internal feedback loops or flows), based on representations that go beyond traditional static forms such as sketches, animations, or real time graphics [1, 9, 37, 42, 43, 53, 58]. Systems thinking focuses on the way that a system’s constituent parts interrelate and
Fig. 7.11  Courtesy of Logos Knowledge Network, Lugano (Switzerland). e-REAL setting with medical imagery on the side walls, a 3D beating heart on the top-right corner of the main screen which can be rotated 360° and can be overlaid with annotations and visualization of medical exams on the top-left corner of the same central wall.

Fig. 7.12  Courtesy of the Red Cross of Italy in Bologna (Italy). e-REAL setting with a perioperative environment mirrored on a wall displaying interactive procedural guidelines. A second small surface (right), made by a simple curtain, is used to project visual mnemonics and check-lists that can be commanded vocally or by the flick of the hands.
Fig. 7.13  Courtesy of the Red Cross of Italy in Bologna (Italy). e-REAL setting designed for crisis resource management enhanced by visualization of the available therapeutic alternatives, with a tracking system to keep track of all the decisions taken. By clicking a virtual button, learners may directly pop-up medical imagery to achieve a deeper understanding of the situation they are dealing with.

Fig. 7.14  Courtesy of the Red Cross of Italy in Bologna (Italy). Simulation’s closing phase designed to allow the instructors to provide a rapid first debriefing regarding both the therapeutic decisions taken by the learners and the verbal communication with the patient. Guidelines are available for a rapid search on the side curtain (right).
Fig. 7.15  Courtesy of the Red Cross of Italy in Bologna (Italy). Wall mirroring with personal tablets and smartphones within an e-REAL setting

Fig. 7.16  Courtesy of Logosnet, Houston (TX, USA). In situ simulation setting for residents and interns, enhanced with an e-REAL system displaying interactive check-lists and mnemonics, 2-3D images and videos on two common walls
Fig. 7.17  Courtesy of Logosnet, Houston (TX, USA). Setting for in situ simulation enhanced with an e-REAL system displaying 2-3D images and videos on a common wall

how systems work over time and within the context of larger systems—contrasting with traditional analysis, which studies systems by breaking them down into their separate elements.

With e-REAL, briefing and debriefing phases are performed by:

- Representing or summarizing a case with visual storytelling.
- Showing a video during which you can write relevant key-words, highlight details, and add related multimedia content to the screen to enrich the cognitive map.
- Clustering relevant concepts and key-words on an electronic whiteboard.
- Moving content from one wall to another.

2. **Use of the interactive wall with the smart interactive whiteboard tool for briefing and debriefing phases**

The e-REAL touch-walls (or e-Walls) work both as virtualized electronic whiteboards and as interactive scenarios. This is a virtualized model, developed without the limitations of the electronic whiteboards.

The e-REAL system is commonly operated using simple gesture or spoken commands. The system is an interactive surface designed to: (1) enhance briefing and debriefing sessions; (2) dynamically visualize on a large surface; (3) cluster
Fig. 7.18 Overlaying of notes on a brain cancer displayed on the CMS-e-REAL wall. Courtesy of the Center for Medical Simulation in Boston (CMS-MA, USA) and—from the left to the right—of Robert Simon (Principal Consultant at CMS), Roxane Gardner (Senior Director Clinical Programs and Director of the Visiting Scholars and Fellowship Program at CMS), Sarah Janssens (Director of Clinical Simulation at Mater Education in Brisbane, AUS), David Gaba (Associate Dean for Immersive and Simulation-based Learning and Director of the Center for Immersive and Simulation-based Learning at Stanford University School of Medicine, CA), Stephanie Barwick (Head of Partnerships, Programs and Innovation at Mater Education in Brisbane, AUS)

Fig. 7.19 Courtesy of the Center for Medical Simulation in Boston (MA, USA). Use of behavioral and cognitive key performance indicators during a debriefing: the e-REAL features allow writing and annotation, highlighting, erasing, moving, clustering, packing within the boxes or unpacking again two or more tags
concepts and notes; (4) to physically touch and grasp ideas and multiple perspectives; (5) make the intangible, tangible; (6) facilitate cooperative learning; and (7) encourage systems thinking.

- A number of writing and annotation functions make it possible to write, draw, highlight, color pick, erase and delete on any background (e.g., movie, scenario, written text).
- A snapshot function allows users to save a screenshot (in PNG format) into a user’s predefined folder securing all the annotations. If mailing lists are available, screenshots may be directly sent.
- A multimedia gallery is available to store content that can be uploaded (videos, audios, images, PDF files) by the instructor and projected on the wall simply by tapping on them, to facilitate the instructor’s ease to undertake briefings and debriefings.
- Another tool allows users to move, rotate and scale content. It is also possible to create a group in order to cluster concepts and elements (words, images, etc.) that can be packed in boxes and unpacked, moved, rotated and scaled all together.
- Puzzles can be created and played on the wall as a multi-perspective exercise. Puzzle pieces can be moved and rotated. When a piece fits, it is “magnetically” stitched to the other(s), when the puzzle is complete, it is converted to an Image Widget (so that it can be moved, rotated, etc.).

3. Simulation phase

The simulation phase is strongly enhanced by the e-REAL system, through the multisensory scenarios embedding virtual and augmented reality elements and tools.

Digital content can coexist with tools from the real world, such as a patient simulator and/or a medical trolley that can be on-stage during a briefing or a debriefing phase or a simulation phase within a virtualized environment.

Learners usually work on and around one or more patient simulators—i.e. mannequins with lifelike features and, usually, with responsive physiology—or simulated patients like actors or avatars, or in a disaster scenario. They are asked to make critical decisions, complete physical exams, recognize a situation requiring rapid intervention, practice technical skills, communicate with a patient, and the health care team, interpret test results. Learners are also trained to manage unforeseen events between parallel processing (that is, more than one task at a time) or performing one task at time in a sequence—taking into consideration critical contextual factors such as a lack of time, scarcity of resources and tools, and previous impacting factors.

Similar to being immersed within a videogame, learners are challenged by facing cases within multifaceted medical scenarios that present a “more than real” wealth of information. This is augmented reality in a hybrid environment—which contributes to individual cognitive maps by enabling a multilayer view and making the invisible, visible, the anatomy under the skin of the patient simulator can be enlarged, turned or rotated to appreciate how structures are interrelated.
4. Virtual patients and other avatars, real or virtual tools and devices

Within the e-REAL simulation setting, medical tools and devices can be real or virtual. When they are virtual, usually they are high fidelity models.

It is also possible to replace physical simulation mannequins with custom-made 3D virtual patients (avatars). Whether obese, pregnant, young, old, vomiting, missing limbs, bleeding, or expressing any number of other physical signs and symptoms, e-REAL enables reproduction of patients (in a number of places, such as the Simnova Center for Medical Simulation from the University of Eastern Piedmont in Novara, Italy).

5. Augmented reality (AR) displays

AR displays can be easily embedded within the e-REAL setting. Using AR, for example, a procedure can be performed partly in the real world and partly in the AR environment, or an entire procedure can be performed via “telemedicine” by an operator wearing special glasses and guided by an expert, who is tracking and keeping record of the info captioned by the AR displays.

AR allows knowledge sharing and cooperation among persons and teams. Learners can cooperate by sharing a virtualized common scenario, displayed on the e-REAL wall, even when they are performing in different physical environments. They can talk to each other and look at their own avatars acting in the same virtualized scenario because of special sensors capturing the body’s dynamics.

6. Holograms

Holograms may be part of the e-REAL setting, utilizing wearable augments such as special glasses: Microsoft Hololens™, Epson Moverio™, etc. https://youtu.be/nrzdKzvKbIw (courtesy of the Polytechnic School of Turin, the University of Eastern Piedmont, Simnova Center in Novara, and Centro Studi Logos, Turin, Italy).

Also human-sized holograms can be reproduced within the e-REAL setting. Those holograms may be pre-recorded or may even be live, talking and interacting dialogically with the learners.

https://youtu.be/E2awcWvfqNA (courtesy of Logosnet, Houston, TX, USA).

7. Speech analysis as a further option for the debriefing phase

Speech analysis is a powerful training tool to track—individually—both the tone of voice and spoken words of the learners, providing a semantic and pragmatic overview of interpersonal communication.

According to the Polytechnic School of Turin and to ISTI-CNR (a branch from the Italian Research Council), the fidelity of a speech recording and transcription is approximately 94%. An operator, such as a simulation engineer, may be able to amend and modify the transcript so that the fidelity of the transcript achieves 100% semantic accuracy [19, 38].

Functions and visual outputs include the following:
An integral transcript or a dialogue which can be visualized.

Audio clips, automatically divided phrase by phrase, are also available.

A word counter shows the number of spoken words per minute.

An internal search engine enables keyword search, highlighting the words in the transcript.

A word cloud tool visually summarizes the most spoken words.

A Voice Analysis tool is available in order to measure and visualize waveform (Decibel), perceived loudness (Hertz) and pitch.

Some of these features are visible in Fig. 7.6.

A video introduction is available via the following URL: https://youtu.be/3-hOdSYOmwg (courtesy of Centro Studi Logos, Turin, Italy).

7.5 Visual Storytelling and Contextual Intelligence, Cognitive Aids, Apps and Tools to Enhance the Education Process in a Simulation Lab or In Situ

Visual storytelling techniques are part of the simulation scene, to represent a realistic context where learners are proactively involved to analyze scenarios and events, to face technical issues, to solve problems. The most effective learning occurs when being immersed in a context: realistic experience is lived and perceived as a focal point and as a crossroad [33].

Effective visualization is the key to help untangle complexity: the visualization of information enables learners to gain insight and understanding quickly and efficiently [24, 78, 79]. Examples of such visual formats include sketches, diagrams, images, objects, interactive visualizations, information visualization applications and imaginary visualizations, such as in stories and as shown in Figs. 7.20 and 7.21.

Visualizations within e-REAL show relationships between topics, activate involvement, generate questions that learners didn’t think of before, and facilitate memory retention. Visualizations act as concept maps to help organize and represent knowledge on a subject in an effective way [17, 24, 78, 79].

Half of the human brain is devoted directly or indirectly to vision, and images are able to easily capture our attention [81]. Human beings process images very quickly: average people process visuals 60,000 times faster than text [56]. Humans are confronted with an immense amount of images and visual representations every day: digital screens, advertisements, messages, information charts, maps, signs, video, progress bars, diagrams, illustrations, etc. [1, 18, 26, 27, 31, 34, 59, 66, 78, 79, 85]. The use of symbols and images are extremely effective to warn people, as they communicate faster than words and can be understood by audiences of different ages, cultures and languages [35]. Images are powerful: people tend to remember about 10% of what they hear, about 20% of what they read and about 80% of what they see and do [39].
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**Fig. 7.20** Courtesy of Centro Studi Logos, Turin, Quadrifor, Rome, and the Polytechnic School of Milan (Italy): e-REAL simulation lab to deliver the training program “Big Data for Beginners” (designed and taught by Fernando Salvetti) aimed at growing a digital mindset and skills related to big data visualization.

**Fig. 7.21** Courtesy of Centro Studi Logos, Turin, and Simnova, Novara (Italy): e-REAL simulation lab at the Simnova Center from the University of Eastern Piedmont in Novara (Italy) held during the SimCup of Italy 2019, open to all the Italian medical and nursing schools students and attended by hundreds of learners cooperating in teams comprised of 4 members each.

Contextual factors are key to learning [33]. In e-REAL, learners practice handling realistic situations, rather than learning facts or techniques out of context. Context refers to the circumstances that form the setting for an event, statement, or idea. Context related factors can be influential and even disruptive: for example, a loud background noise within a virtually recreated operating room in e-REAL impacts...
negatively on the surgical team’s ability to communicate and may consequently contribute to their committing an error. The most effective learning occurs through being immersed in context, requiring the ability to understand the limits of our knowledge and action, and to adapt that knowledge to an environment different from the one in which it was developed [33, 36].

A context related experience within an e-REAL setting is similar to being immersed within a videogame with our entire bodies. Characteristics of games that facilitate immersion can be grouped into two general categories: those that create a rich mental model of the game environment and those that create consistency between the things in that environment [12, 83, 84].

The richness of the mental model relates to the completeness of multiple channels of sensory information, meaning the more those senses work in alignment, the better. The richness also depends on having a cognitively demanding environment and a strong and interesting narrative. A bird flying overhead is good. Hearing it screech is better. Cognitively demanding environments in which players must focus on what’s going on in the game will occupy mental resources. The richness of the mental model is good for immersion, because if brain power is allocated to understanding or navigating the world, it’s not free to notice all of its problems or shortcomings that would otherwise remind them that they’re playing a game. Finally, good stories—with interesting narratives, credible because intrinsically congruent as much as possible [6, 13, 22, 32, 45, 54]—attract attention to the game and make the world seem more believable. They also tie up those mental resources [84].

Turning to game traits related to consistency, believable scenarios and behaviors in the game world means that virtual characters, objects, and other creatures in the game world behave in the way in which learners expect [12, 84]. Usually game developers strive for congruence among all the elements.

Learners are challenged both cognitively and behaviorally in a fully-immersive and multitasking learning environment, within interactive scenarios that usually present also a wealth of information. The many levels of the situation are made available simultaneously, by overlaying multisource—words, numbers, images, etc.—within an environment designed by AR techniques [4] (Fig. 7.22).

e-REAL submerges learners in an immersive reality where the challenge at hand is created by sophisticated, interactive computer animation. Importantly, the system includes live and real time interaction with peers, instructors, tutors, facilitators and mentors. Thus, it adds a very important social component that enhances learning outputs, skills, cognitive and metacognitive processes.

The process of learning by doing within an immersive setting, based on knowledge visualization using interactive surfaces, leaves the learners with a memorable experience [70] (Fig. 7.23).

From an educational perspective, learners are not assumed to be passive recipients and repeaters of information but individuals who take responsibility for their own learning. The trainer functions, not as the sole source of wisdom and knowledge, but more as a coach or mentor, whose task is to help them acquire the desired knowledge and skills.
A significant trend in education in the nineteenth and twentieth centuries was standardization. In contrast, in the twenty-first century, visualization, interaction, customization, gamification and flipped learning are relevant trends [63]. In a regular flipped learning process, students are exposed to video lectures, collaborate in online discussions, or carry out research on their own time, while engaging in concepts in the classroom with the guidance of a mentor. Critics argue that the flipped learning model...
has some drawbacks for both learners and trainers [63]. A number of criticisms have been discussed with a focus on the circumstance that flipped learning is based mainly on video-lectures that may facilitate a passive and uncritical attitude towards learning, in a similar way to didactic face-to-face lectures, without encouraging dialogue and questioning—within a traditional classroom [8, 48, 72, 74, 76, 77].

The e-REAL setting is a further evolution of a flipped classroom, based on a constructivist approach. Constructivism is not a specific pedagogy, but rather a psychological paradigm that suggests that humans construct knowledge and meaning from their experiences. From our constructivist point of view, knowledge is mainly the product of personal and interpersonal exchange [10, 41, 52, 55, 60, 63, 64]. Knowledge is constructed within the context of a person’s actions, so it is “situated” [52]: it develops in dialogic and interpersonal terms, through forms of collaboration and social negotiation. Significant knowledge—and know-how—is the result of the link between abstraction and concrete behaviors.

Knowledge and action can be considered as one: facts, information, descriptions, skills, know-how and competence—acquired through experience, education and training [10, 60]. Knowledge is a multifaceted asset: implicit, explicit, informal, systematic, practical, theoretical, theory-laden, partial, situated, scientific, based on experience and experiments, personal, shared, repeatable, adaptable, compliant with socio-professional and epistemic principles, observable, metaphorical, linguistically mediated [52]. Knowledge is a fluid notion and a dynamic process, involving complex cognitive and emotional elements for both its acquisition and use: perception, communication, association and reasoning. In the end, knowledge derives from minds at work. Knowledge is socially constructed, so learning is a process of social action and engagement involving ways of thinking, doing and communicating [67, 68, 82].

Compared to a traditional learning approach incorporating didactic lessons, learner performance gain was found to be 43%, in terms of increased speed and ease of learning, as reported by students, and 88% of learners also reported increased engagement and enjoyment as demonstrated in the tests performed by the applied research team at the Environmental Design and Multisensory Experience Lab from the Polytechnic School of Milan (Italy). These results have been accepted for presentation at ICELW 2020 (Columbia University, New York), and briefly discussed within a research paper [15]. Moreover, due to the decreased cost of the e-REAL immersive room compared to CAVE-like environments, the e-REAL’s added value is even more evident.

The e-REAL environment, to be experienced in a natural way without special glasses, is supposed to reduce the extensive use of the brain’s working memory that is overloaded by traditional lectures [21, 47, 73], and during conversion of a 2D to a 3D representation as what usually happens with common images used during traditional teaching [66]. Tests and experiments are in progress at the Polytechnic School of Milan and at the Center for Medical Simulation in Boston, to explore educational outputs related to cognitive aids, displayed as VR objects usually on a wall and sometimes within AR glasses or by indoor micro-projection mapping directly on the mannequins or on the other tools available as skill trainers [15].
Throughout the simulation process (briefing, performance, debriefing) both within a simulation lab or in situ, learners can interact with the content using spoken commands or natural gestures without the constraint of wearing glasses, gloves or headsets, nor joysticks (when they wish, they can use active pens instead of their fingers). No screens are needed: e-REAL sensors turn any surface into a touch screen.

### 7.6 The Epistemological Pillars Supporting e-REAL

The e-REAL learning approach is designed to have the learner working on tasks that simulate an aspect of expert reasoning and problem-solving, while receiving timely and specific feedback from fellow students and the trainer. These elements of deliberate practice [25] and feedback are general requirements for developing expertise at all levels and disciplines and are absent in lectures [44, 62, 71].

During an e-REAL session, both clinical and behavioral aspects of performance are addressed. A number of skills and competencies both technical and non-technical (behavioral, cognitive and meta-cognitive) are challenged: on one side technical knowledge and know-how, and, on the other side, behavioral, cognitive and metacognitive skills, leadership and followership, team-work facilitation, team spirit and effectiveness, knowledge circulation, effective communication, relationships and power distance, fixation error management and metacognitive flexibility. Feedback is provided throughout sessions with a focus on key performance indicators.

The e-REAL system allows trainers to feedback about key aspects of performance, using different tracking options. The system also allows multi-source feedback during the simulation-based session, combining self-assessment, feedback from the other participants and the trainer. This activity improves the learners’ awareness of their own competencies.

Summarizing, we can say that e-REAL is a set of innovative solutions aimed at enhancing learning with a systemic, multilayer and multi-perspective approach. Tools such as speech analysis, visual communication and conceptual clustering are part of the solution.

Integrating—and enhancing—technical skills with these related to the behavioral, cognitive and metacognitive domains is a major aim. Innovations based on visual thinking and immersive learning, (such as e-REAL, other augmented reality tools, advances in tablet technology and mobile applications, wearable devices and multimedia libraries), are successful because they upgrade people’s knowledge, skills and abilities.

The main goal within e-REAL is allowing a multi-perspective mindset during a simulation session. Visualizing the “invisible” by overlaying information that focuses on both technical and behavioral aspects of a performance, and merges the virtual and the real, creates a multilayer and therefore augmented, multi-perspective, and systemic simulation that contributes to a better understanding.

Nothing is revolutionary within a simple VR headset, but if VR content and scenarios are “actualized” [40]—or enhanced—within a real simulation setting, the
merging of the real and virtual world adds value to the learning process. In such a way, e-REAL becomes more than real!

7.7 Case-Study: Teamwork and Crisis Resource Management for Labor and Delivery Clinicians

1. The program and a key cognitive aid: Name-Claim-Aim

Teamwork and Crisis Resource Management for Labor and Delivery Clinicians (Introductory and Advanced Levels) is experiential coursework focused on learning and improving teamwork and event management during simulated obstetrical cases. It is an interprofessional program based on advanced simulation, delivered many times per year in Boston (MA, USA) at the Center for Medical Simulation (CMS) in a realistic clinical setting [51, 69]. Each case is immediately followed by a facilitated debriefing led by experienced instructors and faculty members of CMS. Participants include obstetricians, obstetrical nurses, midwives and obstetrical anesthesiologists. e-REAL is integrated into this program and used to deepen learning and to enhance cognitive retention of the main mnemonic used during the program [14].

Effective team management during a crisis is a core element of expert practice. Medical simulation can contribute enormously to enhance teamwork during a crisis [28], fostering situational awareness and contextual intelligence [36] which refers to the abilities to apply knowledge to real world scenarios and situations, as well as cognitive retention of essential steps and procedures to be performed during an ongoing crisis.

A crisis management organizational approach using a mnemonic called Name-Claim-Aim is being used in order to facilitate crisis management and decision making: knowledge and skills are essential components of the decision-making and the actions performed during crises, but they are not sufficient to manage the entire situation which includes the environment, the equipment and the patient care team.

After several decades worth of dedicated simulation education for anesthesiologists and labor and delivery teams, teamwork experts at the CMS have found that these teams still struggle to routinely organize themselves in crises during simulation courses, let alone in the clinical environment [50, 51]. Stories from course participants of all professions indicate that there exists a real challenge to both focus on the clinical picture and apply organizational principles to the team, and more often than not, the organization within the team is under-prioritized. Part of this may be due to the intense cognitive load experienced by those who are managing a stressful clinical crisis. It can be difficult to also remember the eleven crisis resource management (CRM) principles introduced by Gaba et al. [28] and apply them routinely while actively managing a resuscitation (Fig. 7.24).

Appreciating the impact of stress on high level thinking [2], faculty at CMS collapsed these 11 key points into 5 key CRM concepts of role clarity, effective
communication, effective use of personnel, effective management of resources and global assessment (Fig. 7.25).

The role of “Event Manager,” rather than “Team Leader,” is expressly promoted at CMS to facilitate distributed leadership in crises. This distinction has proven to be effective in teams of expert practitioners because it deliberately seeks to flatten hierarchies which may inhibit speaking-up behavior from team members, which may successfully counteract failures of perception [57]. The Event Manager coordinates the communication and the team’s efforts, overseeing the organization and application of CRM principles, in addition to actively soliciting input and decision-making regarding medical care, if necessary. Moreover, the Event Manager acts to facilitate role designation, orchestrate and coordinate team function.

Based on these challenges, the mnemonic “Name-Claim-Aim” was developed at CMS to incorporate 10 of the 11 CRM principles in an easy-to-remember, and easily applied, framework (Fig. 7.26). Cognitive aids were developed to help facilitate learning of this mnemonic and an “Event Manager Checklist” was created to facilitate effective role designation. Participants have been given this cognitive aid, designed as an ID badge-sized card, to easily access during their simulation course. In addition, the “Name-Claim-Aim” and “Event Manager Checklist” have been adopted by the Massachusetts General Hospital (MGH) (Boston, MA, USA) for inclusion in the latest version of their Emergency Manuals (Figs. 7.27 and 7.28).
Rapid Cycle Deliberate Practice (RCDP) is a novel simulation-based education model that is currently attracting interest, being implemented, explored and researched. In RCDP, learners rapidly cycle between deliberate practice and directed feedback within the simulation scenario until mastery is achieved [75]. Common RCDP implementation strategies include: splitting simulation cases into segments,
micro-debriefing in the form of “pause, debrief, rewind and try again” and providing progressively more challenging scenarios. During the Labor and Delivery program, clinicians are shown short dynamic videos: they are challenged to recognize a situation requiring rapid intervention, communication, knowledge sharing, decision-making and management of unforeseen event—while taking into consideration critical contextual factors such as a lack of time, scarcity of resources and tools, and a multitude of additional impactful factors. e-REAL is being used, enabling learners to interact with multimedia scenarios recreating very different situations [69]. Learners are requested to be compliant with the Name-Claim-Aim mnemonic to manage the
crisis by coordinating the team roles and efforts. The interactive videos feature unexpected clinical or non-clinical, emergent scenarios, including extreme, dangerous environmental threats (Figs. 7.29, 7.30 and 7.31).

**Fig. 7.29** Courtesy of the Center for Medical Simulation (CMS) (Boston, MA), the Polytechnic School of Milan (Italy) and Logosnet (Houston, TX): Interactive e-REAL wall with a number of tailored multimedia content ©

**Fig. 7.30** Courtesy of the Center for Medical Simulation (CMS) (Boston, MA), the Polytechnic School of Milan (Italy) and Logosnet (Houston, TX): Alpine environment with photorealistic avatars expected to occur a sport traumatism ©
3. **Multilayer vision for an enhanced use of neural processes: key questions**

The e-REAL system enables a multilayer vision: the many levels of the situation are made available simultaneously, by overlaying multisource info—e.g. words, numbers, images, etc. Visualizations show relationships between topics, activate involvement, generate questions that learners didn’t think of before and facilitate memory retention. Visualizations function as concept maps to help organize and represent knowledge on a subject in an effective way.

By visualizing relations between topics, contextual factors, cognitive maps and dynamic cognitive aids [27], e-REAL allows more effective learning and storing of information into memories based on experiences and practice. At the same time, e-REAL helps instructors to immediately identify errors and difficulties of the trainees, facilitating an effective debriefing (Figs. 7.32, 7.33 and 7.34).

### 7.8 Conclusion

As Pierre Lévy was used to say, reality in the digital age is becoming more and more virtual [40]. In healthcare simulation, the dematerialization of the learning environment is allowed by new technologies that offer options to improve the usability of traditional e-learning methods. Sharing and mixing up the latest trends from digitalization and virtualization, neurosciences, artificial intelligence, and advanced simulation allows us to establish a new paradigm for education and training.

So far, the ongoing exploratory projects within the e-REAL set up at the Center for Medical Simulation in Boston are:
1. The further use of the e-REAL visualizations in Labor and Delivery programs and in Anesthesia programs.

2. The design of distance-based simulations to take care of COVID-19 related situations: logistics, team safety, relationship with patients and families.

3. The introduction of online learning modules where different types of virtual objects are co-existing: artificial but realistic avatars and real actors performing as standardized patients or family members or colleagues, photorealistic 3D tools, indoor or outdoor scenarios.

4. The development of self-learning solutions to improve results related to critical conversations, debriefing sessions, video-interviews and video-conferences.

5. The use of AR head-mounted displays to provide guidance during remote on-site simulations.

6. The visualization of check-lists and mnemonics (virtualized and displayed on screens or walls) to foster team performance.
Fig. 7.33  Courtesy of the George Washington University School of Nursing (Ashburn, VA), and Logosnet (Houston, TX): Outdoor scenario designed to allow learners to visually detect difficulties and risks related to an emergency situation

Fig. 7.34  Courtesy of the George Washington University School of Nursing (Ashburn, VA), and Logosnet (Houston, TX): A detail from an outdoor scenario designed to allow learners to visually detect difficulties and risks related to an emergency situation
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