Interactive Holograms and Tutorials in Healthcare Education: Case Studies from the e-REAL® Experience

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***Abstract*—With both portable and permanent fixtures available, the e-REAL lab encompasses users in an entirely interactive and immersive ecosystem; advanced medical simulation reaches its best thanks to interactive 3D holographic visualization. Using a number of tools, e-REAL enables not only face-to-face training, but also e-learning and remote communication across the globe.**

***Index Terms*—e-REAL, enhanced reality tools, holograms, immersive medical simulation, interactive tutorials.**

I. INTRODUCTION

e-REAL is a powerful tool based on Enhanced Reality technologies, designed for lifelong learning, capacity building, educational events, interactive edutainment, and immersive experiences.

e-REAL - which stands for Enhanced Reality Lab - is a solution like no other, at the forefront by design, developed since 2011 in order to evolve from the old CAVE environments (too rigid, difficult to be managed and expensive) to an easy, user-centered and cost-effective solution. It is so simple that two buttons are enough to manage it all.

e-REAL offers a unique combination of immersive training programs based on visual communication and a direct interaction with the contents.

The e-REAL lab immerses people in an entirely interactive ecosystem – enabling both face to face and virtually limitless e-learning and remote communication across the globe [1]. Sample activities are those shown in the figures below:

Figure 1. e-REAL lab: Interaction with 2D and 3D images projected by very powerful ultra-short throw projectors (allowing a CAVE-like setting easier, more powerful and 20 times less expensive)

Figure 2. e-REAL lab: Interaction with a repository linked to a virtual tutoring system enabling knowledge dissemination about clinical cases, innovative protocols, new techniques

Figure 3. e-REAL lab: 360-degrees floating hologram surrounded by 2D and 3D images

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

- Multimedia libraries
- Interactive tutorials
- Holographic visualizations
- Real-time and live holograms
- Podcasts and apps
- Wearable devices such as glasses, headsets, watches and gloves.

II. THE PRIMACY OF VISUALIZATION

The most effective learning occurs through being immersed in context. Experience is lived and perceived as a focal point and as a key crossroad.

With both portable and permanent fixtures available, e-REAL is an ever-expanding ecosystem of immersive experiences, apps and tools - where a number of contents are available off-the-shelf. It is a visual, eye catching, attention attracting, immersive and amazing ecosystem - enabling learners to do many activities using gestures and spoken commands.

Moreover, it can be easily customized with a number of exceptional multimedia contents (mainly regarding clinical cases) and augmented reality tools: 2D and 3D multimedia libraries, interactive tutorials and cases, wearable devices, holographic visualizations, real-time and live holograms broadcast from anywhere (thanks to an effective solution allowing a low consumption of broadband, recently jointly patented by a sister company and the Italian Research Council).

All of it is easy, simple and effective: in the lab a couple of buttons manage everything and there is always support staff available that can manage all the solutions remotely.

When it comes to learning, complex doesn't always equal complicated.

Learning implies coping with complexity, but a good educational methodology allows learners to learn in a simple way. Simplified learning doesn't mean impoverished concepts and reasoning, but, on the contrary, making complexity graspable.

Effective visualization is the key to help untangle complexity: the visualization of information enables us to gain insight and understanding quickly and efficiently.

Examples of such visual formats include sketches, diagrams, images, objects, interactive visualizations, information visualization applications and imaginary visualizations as in stories and as shown in the frames above.

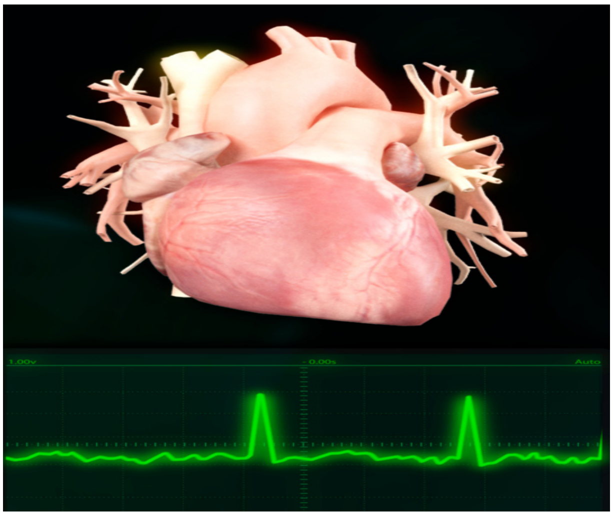


Figure 4. Interactive tutorial on atrial fibrillation working on mobile devices and laptops as well as within the e-REAL labs

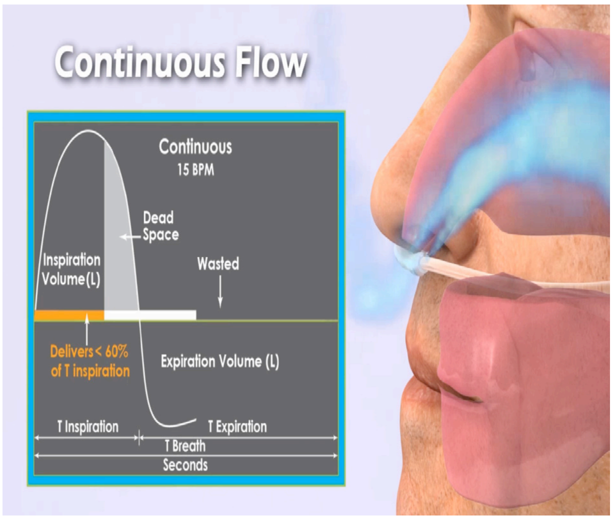


Figure 5. 3D dynamic images from an interactive edugraphic by Amerra, a leading advanced medical communication company.

Figure 6. e-REAL lab: 360-degrees floating 3D image working also on mobile devices and laptops

Half of our brain is devoted directly or indirectly to vision. Images are able to grab our attention easily. We process images very quickly: researchers suggest that people process visuals 60,000 times faster than text. This is why we 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. If we have to warn people, symbols and images are excellent: they communicate faster than words and can be understood by audiences of different ages, cultures and languages [2].

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.

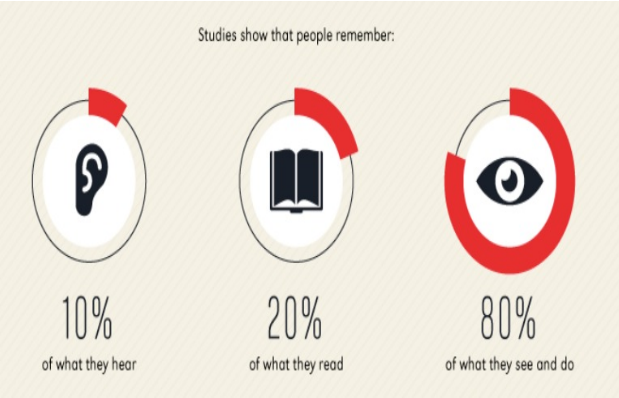


Figure 7. Infographic about the power of visual communication

Our visualizations show relationships between topics, activate involvement, generate questions that learners didn't think of before and facilitate memory retention. Within e-REAL we create visualizations that act like concept maps and that help organize and represent knowledge on a subject in an effective way.

Edugraphics are the infographics used in the e-REAL ecosystem: not simply illustrations, but an innovative way to present a subject with a larger graphic design that combines data visualizations, illustrations, text and images together into a format that tells a complete story.

A good edugraphic must be unique and impactful, or it won't be memorable to the audience. There are different forms: static, zooming, clickable, animated, video and interactive. The more interactive and dynamic they are, the more powerful and effective. For example, the following holographic images, regarding a training program on atrial fibrillation:

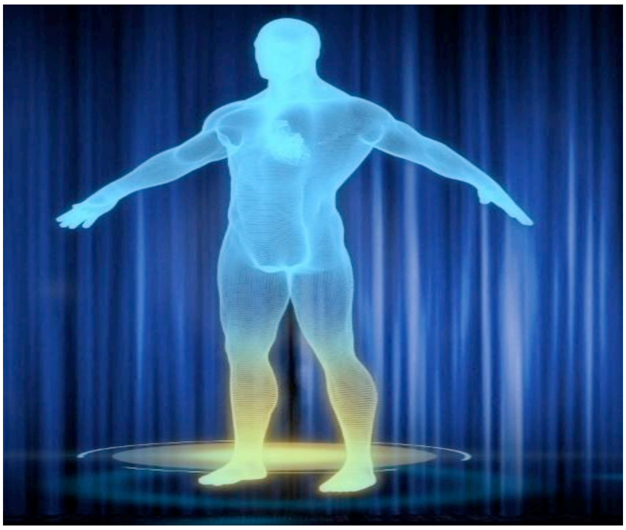


Figure 8. 360-degrees floating edugraphic for clinical case's analysis: human-sized hologram

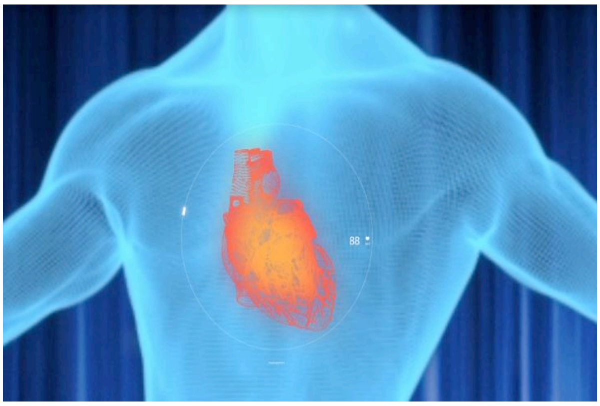


Figure 9. 360-degrees floating edugraphic for clinical case's analysis: beating heart

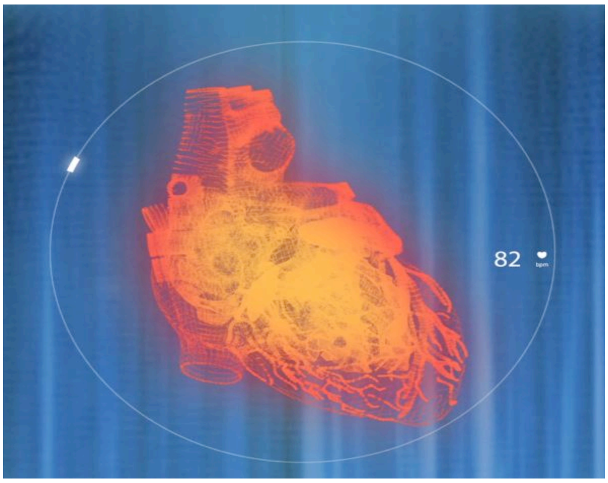


Figure 10. The 3D holographic representation of the beating heart

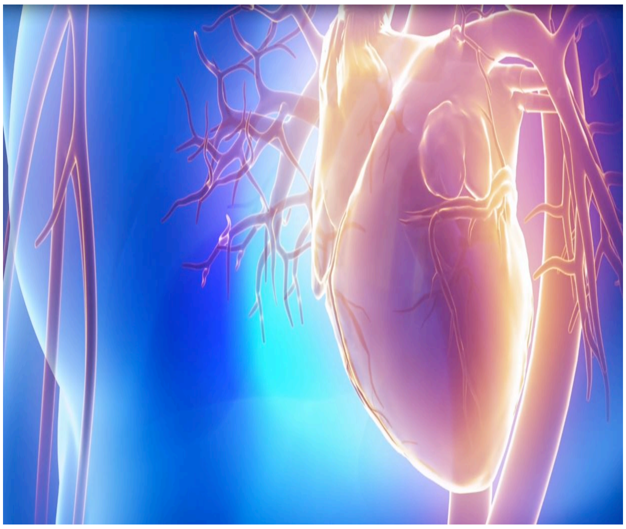


Figure 11. Different 3D holographic representation of a beating heart

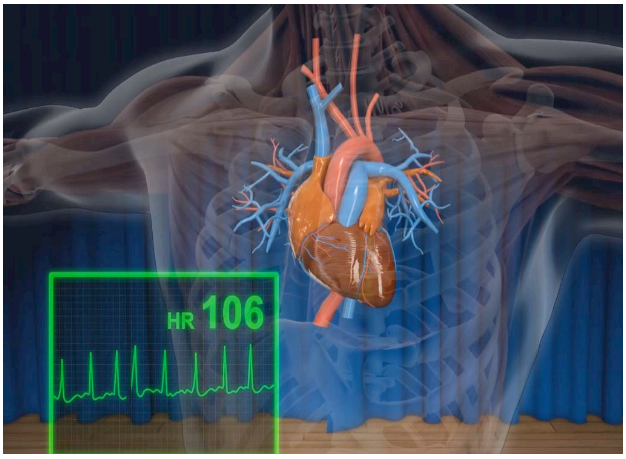


Figure 12. Interactive tutorial for ECG clinical case

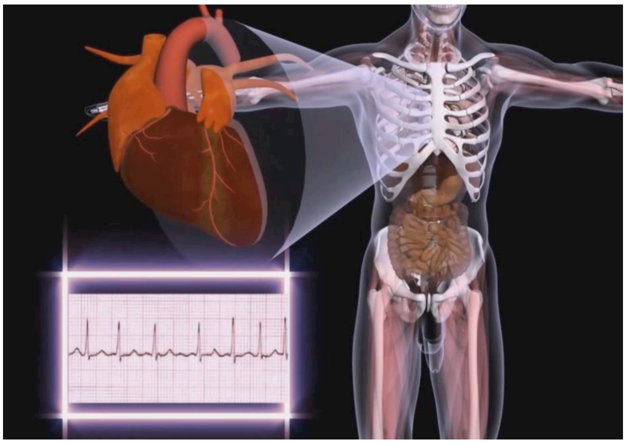


Figure 13. Dynamic 3D holographic representation for ECG clinical case

Looking at the above images we gain an immediate first level of understanding, but the success of those edugraphics is that they stimulate our investigation; a lot of questions arise from the 360-degrees and 3D visual exploration of the images – enriched also by the interactivity. So, what are the characteristics of an effective edugraphic?

a) It is a graphic visual representation of information, data or knowledge that makes complex topics easy to be understood - showing us the trends and implications that underlie data.

b) It combines data visualizations, illustrations, text and images together in an interesting, eye-catching and engaging way, increasing learners' attention, understanding and memorization of the topics.

c) It has to support a personal exploration from different perspectives: a unique snapshot with a possibility to embrace all the complexity of the topic, zooming out for a global vision and immediately zooming in on a simple detail.

d) It works like storytelling, communicating complete stories and putting information in a context showing relations and comparisons, to make the topics easily understandable and to promote critical thinking.

e) It works like a concept map extracting the patterns that underlie data and information, helping us to think in terms of the bigger picture, of the patterns that reside within the information.

III. INTERACTION AND IMMERSIVITY

The best edugraphics are interactive: they can be presented by the trainer or the learning facilitator and then learners can discuss in small groups and study in-depth the topics. Conceptual maps and interactive edugraphics are presented showcasing the main concepts of visual case-studies, realistic scenarios, video clips, etc.

The e-REAL setting allows a very innovative and effective way to enhance the learning experience by the use of visuals: learners are completely surrounded and immersed in the 2D, 3D, or holographic images and movies. They can explore and interact with the images using touch sensors, thanks to very responsive proximity devices developed by two US partner companies (Leap Motion and Ubi Interactive).

As the age of innovation & technology advances, traditional communication and learning environments are left several steps behind the ongoing revolution. The e-REAL lab eliminates the gap between rapid technological growth, outdated communication and learning methods.

Because information technologies evolve, so do the possibilities for more immersive learning and teaching techniques. Within e-REAL, for instance, we are using cutting edge technologies to create both a virtual and a physical ecosystem, which immerses people in real life situations, with possibilities to interact simultaneously with peers, tutors and learning facilitators, thematic experts and colleagues (both on-site and remotely), as well as consulting literature, records and other written information (that are available as multimedia content).

Much like being immersed within a videogame, people are challenged by facing real cases within complex scenarios that present a "more than real" wealth of information. This is because the many levels of the situation are made available simultaneously, as shown in the below figures.

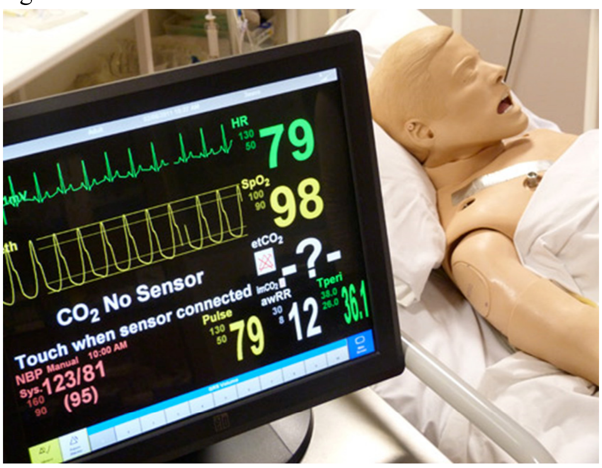


Figure 14. Immersive medical simulation - within a mixed reality setting put in place by LKN & Accurate - to help healthcare teams achieve their full potential within e-REAL: basically by a dummy, selected medical tools, projections on the surrounding walls.

Figure 15. Other sample immersive medical simulation

e-REAL submerges learners in an immersive reality where the challenge at hand is created by sophisticated, interactive computer animation in three dimensions and holographic projections. It further includes live and real time interaction with peers, trainers, tutors, facilitators and mentors. Thus, it adds a very important social component that enhances learning outputs, as well as metacognitive processes (and skills).

As shown in all the figures above, the primary concepts and issues of a particular case can be tackled by visualizing them with the use of holograms (to be seen without 3D glasses or any particular tool), on big screens, or by projecting them directly on walls, ceilings and floors. Users can interact with dynamic holograms, 3D images, sound and vision by moving the body, or with a flick of the hands.

The process of "learning by doing" within an immersive lab, based on knowledge visualization by interactive surfaces (walls, mobile devices, electronic tables, etc.), leaves the attendees with a profound and memorable experience. Attendees are challenged both cognitively and behaviorally in a fully-immersive and multitasking learning environment.

Moreover, e-REAL is an environment that immerses the learners in an "augmented" or enhanced reality where real life situations can be really experienced - within an advanced simulation setting - and the necessary lessons learned without the disadvantage of a negative impact in case of mistakes.

In a nutshell: perfectly portable, with the capability to broadcast vivid life size images, training materials & advanced simulations, the e-REAL lab offers an enhanced-reality ecosystem that is heretofore unparalleled. As a result, people's engagement and performance is expected to grow and it's easy measuring the outputs with the most demanding traceability standards.

IV. INTERACTIVE TUTORIALS AND LIVE HOLOGRAMS: THE FUTURE LEARNING

Interactive tutorials and live holograms are important elements within the e-REAL ecosystem.

Interactive tutorials engage learners through sight, sound and touch, making use of several techniques to promote interaction such as questioning the audience and providing learners with immediate anonymous feedback on their knowledge (mainly by their own personal mobile devices transformed in "clickers" by Poll Everywhere).

Recent reviews of cognitive and motivational effects of small group tutorials [3] showed that small study groups foster interactive learning and positive cognitive effects, such as activation of prior knowledge, recall of information, individual and collaborative knowledge construction, and cognitive conflicts leading to conceptual change. Small group learning was also reported to have a direct positive effect on students' motivation to learn and motivation has been shown to play a central role in promoting group productivity, elaboration of knowledge, and interaction in different settings. Finally, interactive learning has been evaluated more positively than formal lecturing by medical students and medical professionals alike.

Interactive tutorials are at the forefront by design because they are designed to address a topic through multiple representations, following a recursive, non-cumulative, logic [4]. They focus on promoting the capacity to deal with uncertainties and solve problems in an adaptive way. They are made up of multiple resources: each learning object has its own particular shape, perspective and conceptual dimensions. In addition, they are accessible on multiple devices and are designed to be used in multiple ways - such as m-learning, e-learning and within an e-REAL lab as element of a flipped classroom strategy or as a module within an advanced simulation. So they can support multiple teaching strategies - from self-training to cooperative learning within an immersive environment.

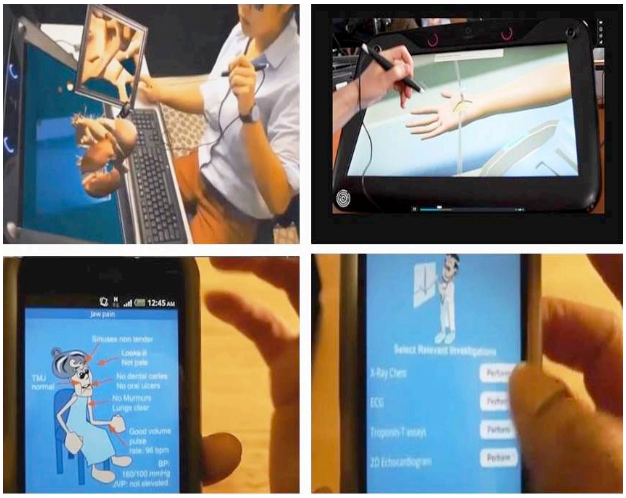


Figure 16. Interactive tutorials samples: 3D (by zSpace glasses and pen) in the upper image, 2D in the lower ones

The realm of simulation has rapidly advanced through the use of technology and the application of instructional design. The next leap is based on holograms.

Our 3D digital holograms allow people to visualize 3D data from every angle and illustrate details that can't be viewed in 2D. They are cutting edge, captivate audiences, don't require glasses and offer a degree of interactivity through channeling and animation.

What 3D holographic technologies offer that other visual forms cannot is the ability to show parts of the human body in a real-life fashion. Furthermore, they are interactive, enabling medical practitioners to not only study images of the body, but to do so easily and from multiple perspectives. The capacity for enhanced visual engagement can benefit research, diagnostic efforts and treatments, as sophisticated 3D software, displays and holograms can be synthesized for a realistic, real-time look at patient conditions.

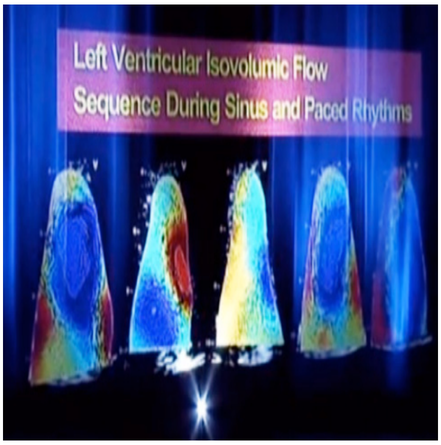
Holography allows the user to view fully parallax, autostereoscopic 3D images. While that capability is still out of reach, current holographic technology is able to present high quality auto-stereoscopic (no-glasses) 3D visuals. Holography began in the 1940s, when Dennis Gabor invented the hologram then won the Nobel Prize. Significant advances occurred when researchers created the first practical hologram using laser illumination. The ability to view holograms using simple white light further revolutionized the field, allowing holograms to begin to move out of the laboratory. With advances in lasers and optics, the fidelity and feasibility of holograms continues to improve [5].

The conceptualization of 3D images within the human brain is a difficult task requiring extensive use of the brain's working memory. In the medical education community, this problem is particularly prevalent due to the complex 3D structures inherent in human anatomy. One solution to this problem is to present medical content in 3D dimensions rather than 2D or 2.5D. In doing so, the trainee would no longer be burdened with the additional cognitive load imposed during conversion of a 2/2.5D representation to a 3D representation within working memory.

The medical holograms treatment presents a significant performance improvement over traditional textbook handouts. There are a number of possible reasons for this improvement. The first is the "wow-factor". Textbook handouts are very commonplace and elicit little inherent interest subsequently. Moreover, the medical holograms are a novel technology, which may garner additional interest and focus from learners. Last but not least, the medical holograms have the advantage of being natively 3D, unlike textbook handouts. As such, the medical holograms may be directly translated to a mental image, while a 2D textbook handout requires 3D reconstruction within the working memory. The resulting mental images from the medical holograms may be superior to textbook handouts due to their immediate translation into working memory.

In the end, the medical holograms may simply provide superior visual capabilities due to their 3D nature. Many anatomical structures are difficult to conceptualize, such as the spatial relationships between various blood vessels, the valves of the heart, and the chambers of the heart. Medical holograms provide additional 3D data to understand these relationships, such as depth cues. The concept of visual grouping suggests that 3D perception relies on grouping visual subcomponents based on textures, color gradients, and continuity of structures.

Within e-REAL, we reach the highest results by associating holographic images with live holograms. In our opinion, the next step relates to a particular learning strategy known as imagery strategy. Imagery strategies involve creating a memory by taking what is learned and creating meaningful visual or auditory mental images of the information, which is one of the main reasons explaining why e-REAL is becoming a landmark technology and educational setting.



Figures 17 and 18. 360-degrees floating holograms commented by an expert broadcasting as a live and real-time hologram

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