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Virtual Reality surgical medical training in the post-Covid-19 pandemic era

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Surgical training has progressed extensively from the historical apprenticeship of the early surgeons to a modern complicated structured training programme with numerous duties and evaluations. Expertise must be gained in a shorter period whilst requiring a greater set of skills than previously. Numerous novel surgical techniques have been developed, demanding the current trainees to learn a broader array of specialist skills, despite having less time to do so. As the number of trainees increases, the chances to acquire procedural and technical skills become gradually limited. Furthermore, the introduction of working hour restrictions and a drive towards senior-led care have reduced the available training hours during the des-ignated training period[1,2].

On the other hand, surgical treatment is now indicated more often than in the past. This, combined with an ageing population with higher treatment needs, has significantly increased the demands for surgery. The ensuing conflict between service provision and training has compelled the development of alternative methods to compensate for the reduction in ‘hands-on’ psychomotor experience.

E-Learning, simulation, and compulsory fellowship training programmes are various solutions that have been proposed to exploit learning opportunities within the existing resource con-straints. Simulation offers to the trainee the chance to obtain surgical skills in a controlled en-vironment while reducing the patient safety risks, operating theatre use and financial expenses[3,4]. Spanning from cadaveric models or arthroscopic simulators to advanced virtual reali-ty sets, there is a wide spectrum of simulation options in orthopaedics. While simulation training has several limitations, it is accepted that trainees need to get procedural experience before real-life practice. The cumulative trainee confidence and familiarity with the equip-ment are apparent advantages, leading to growing evidence that this simulation-gained expertise can be somehow transferred to the operating theatre performance.

Medical simulation is a technology or process that reconstructs the appropriate background, allowing the trainee to come across mistakes and collect feedback in a safe environment[5]. As the technological advances permit more complex situations to be modelled and tested, this definition will continuously grow being more valuable in the ongoing and future training and assessment of surgeons. The advantages of a VR-based simulation extend beyond simple technical and procedural skills. Simulation allows trainees to engage with a multi-disciplinary team and focus on individual and team-based cognitive skills, including problem-solving, deci-sion-making, and team behaviour skills in a realistic, reactive virtual environment, while having a unique hands-on experience.

Recently, considerable progress has been made in evolving novel and diverse simulation-based techniques to deliver virtual training in a protected and flexible environment[6-9]. The simulation improves learner's self-confidence and comprehension while allowing practice and training of specific technical skills[10]. However, real-life surgery is unpredictable mainly be-cause of the unique human anatomy per individual and the incapability to reproduce surgery 100% due to surgical or patient-related factors. During the previous decade, simulation of surgical procedures was mainly limited to a non-operator communication of static, non-interactive image or video-based examples of various procedural steps. Very limited cases of gamified VR approaches have been showcased[11].

Consequently, 3D simulations were not realistic enough for most trainees and of no use for specialist surgeons. The existing, cogni-tive-only virtual simulations were equivalent to a linear, video manual of a flight simulation for a pilot, lacking however any degree of immersive reality or ability to follow and react to dif-ferent scenarios with appropriate user hand-actions (psychomotor). The modern VR simula-tors aim to enhance 3D realism but most essentially to provide a natural, gesture-based in-teraction between the consumer-surgeon and the virtual patient.

Nowadays, the current training models cannot address the vast medical training needs on syrgery and anesthesia-related topics. Moreover, based on OECD estimates, technology is expected to transform roughly more than one-third of all jobs worldwide in the next decade. WHO supports that more than 40 million healthcare professionals will be required by the beginning of the following decade. This increasing demand for a permanent upskill and reskill has become more critical in the post-COVID-19 pandemic. Virtual Reality (VR), along with 5G spatial computing technologies, are presented as the upcoming absolute computing frontline concerning medical psychomotor/cognitive training, education, and empowerment[12].

The renovation of medical training is now accomplished by the virtual/augmented/mixed reality (VR/AR/MR) technologies (grouped by the industry as XR). This transformation is supported by numerous recent academic and industrial articles and case studies[13]. Over 20 clinical trials were published in primary science journals during the last year, evaluating the efficacy of medical VR training in transferring skills from a virtual environment to real-life situations. It has also been demonstrated that XR technologies may significantly improve healthcare professionals' practical and collaborative learning[14].

VR/AR may deliver the ways and methods to achieve remote qualitative education and training skills, via employing inexpensive technology with personalized, on-demand and smooth learning curves. Modern significant advances in 5G networking, spatial computing and neuroscience have demonstrated that the VR/AR shares with the human brain similar fundamental mechanisms like the "embodied simulations".

After more than three decades of intensive research, development and validation by early adopters, the medical VR technologies are now moving into the mainstream. Based on the recent developments in computer vision, innovative algebraic representations, real-time 3D graphics, simulation models, deep learning, gamification, analytics, and 5G cloud edge computing, these spatial computing applications optimize intelligent education & training while maximizing the anticipated learning outcomes. Such immersive technologies may promote lifelong education and offer training programmes and self-improvement opportunities that enhance medical professionals' abilities, reducing the training skill gaps.

It is well known that neuroplasticity and long-term potentiation, which relates to the consoli-dation of neuronal connections in the brain based on current activity patterns, are driven by the feeling of presence and the affordances of agency (body, hand interaction). Repeating the same movement enhances the neuronal cell-to-cell signalling and improves neural connections, strongly influencing learning, muscle, and spatial memory.

Nowadays, therapeu-tic VR has also been clinically proven to help in managing traumas and rehabilitation, phobias, stress and various mental illnesses.

The consequences of the Covid-19 pandemic have speeded up the advances in the field of spatial computing technologies. The 3000 medical schools worldwide, the 8400 medical de-vice companies and the 600 surgical training centres challenged by the covid-19 lockdowns have realized the ultimate need to embody this technology. The use of medical VR training is now not a myth but a modern reality, being part of the so-called “quiet revolution” in this sci-entific field[15]. Besides, health care professionals have now recognized that training simula-tors are the leading application of VR/AR in healthcare. It was recently reported that the growing demand for virtual training across industries drives the VR market, which is expected to grow from $15B in 2020 to $57B in the following years[16].

However, the extensive work of translating the 400+ basic medical procedures and their countless variations is pending[17]. Furthermore, as these medical procedures and the ap-propriate equipment (eg. robotic surgery) are continuously updated, the need for advanced and extensive training is exponentially rising. This constant demand for upskill/reskill in order to follow the latest advances is an endless challenge for healthcare professionals and institutions. Medical professionals and especially med-school students, residents, young or experienced surgeons or physicians of any specialty must continuously attend lec-tures/workshops/conferences and conclude self-training courses to deliver top treatment for their patients, while remaining compliant with the regulatory agencies. Traditionally surgeons are trained on cadavers or on-the-job. However, cadavers are limited and costly, while train-ing on actual patients poses other issues (limited opportunity, repeatability, not to mention possible adverse outcomes). On the grounds of the surpassed time in the operating room for trainees/residents and the fact that constantly fewer of them are entering the workforce, the puzzle is only getting more perplexed over time.

Despite the progress mentioned above, it remains unanswered who will finally transfer the enormous medical-training content in VR technology, both in extensive depth and breadth. Moreover, the lack of dedicated and specifically formed VR content authoring tools for medi-cal training should be noted. Although the outstanding de facto 3D/XR content creation indus-trial standards of Unity and Unreal Engines are employed as the fundamental enabling tech-nologies and general authoring platforms, they provide a general-purpose coverage (from games to automotive, engineering, construction simulation and film/broadcasting). Conse-quently, there is need of experienced doctors motivated in this educational direction as well as of various highly skilled technological developer teams (computer graphics, deep learning, computer networking, human-computer-interaction, gamification, game development, UI/UX design, affective computing), and of course, 3D artists/designers.

Novel integrated software platforms and simulation-training authoring tools are essential, permitting the fast prototyping of medical VR/XR training. These platforms should act in a new computational medical discipline that holds together medical education, preoperative planning, and real-time operative navigation under a new, holistic, integrated system approach. All the involved parts, including medical and dental schools, nursing academies, medi-cal device companies and surgical training centres, should work with teams in-house or out-source parts of the job. However, the final source code owners will empower themselves to update this XR training content effortlessly. By developing, improving, and regulating their own XR training material, they can guarantee that their medical professionals are suitably and uninterruptedly trained while ensuring ideal patient outcomes with fewer medical errors and complications. These novel platforms will serve as the new ‘WordPress’ or ‘Office suite’ of medical VR/XR training so that progressively the subject-matter-experts themselves can create their own VR/AR learning modules, in the same manner they make their presenta-tion slides today. However, there is still a lot of technical work to provide these low-code/no-code authoring platforms[18].

Aerospace and aviation share a lot of similarities in regulatory complexities with the health care industry. For a long time, various aviation authorities have confirmed the exceptional benefits of mandatory simulation-based training of pilots for several aircraft types, leading to the added safety in aviation worldwide. It is widely suggested that medical simulation-based training is absolutely necessary and subsequently, it is probably only a matter of time until VR simulation education labs for training and competency assessment will be mandatory worldwide. Medical education will be considerably improved via experiential learning, since learning by doing has been proven much more effective than the traditional master-apprentice model and the "see one, do one, teach one" concept. The medical institutions must drive themselves medical VR training transformation via XR content curriculum simulators and continuous education of their professionals, for the immediate benefit of their patients with a significant impact on humanity in general.

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