Resuscitation VR: Implementing the Future of Emergency Medicine Training

T. J. Matthews

1 Company Background

i3 Simulations is an immersive technology company that produces augmented reality (AR), virtual reality (VR), and mixed reality (MR) training solutions for the healthcare simulation market. It was spun out of immersive technology incubator AiSolve as an entity focused solely on the healthcare sector and is headquartered in the UK with representation in India, Singapore, and the USA.

The mission statement of i3 Simulations is to democratise learning across healthcare, by designing products for self-guided and peer learning, by flexibility in our business model to outreach underfunded medical institutions, and by supporting content creation and moderation by the subject experts themselves.

T. J. Matthews (✉)
i3 Simulations, Luton, UK
e-mail: tj.matthews@i3simulations.com

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2 Project Summary

Resuscitation VR (Fig. 1) is aimed at the healthcare simulation sector and targeted towards solving problems that occur in training staff for high-stress, critical care environments. It is aimed at training junior doctors (hereby referred to as "residents") and other clinical staff in critical care units (CCUs) across hospitals internationally. Initially sponsored with Oculus (now Meta) funding programme "VR for Good" (Oculus, 2018) as a pilot study, Resuscitation VR has since been formally launched in 2019 and currently has sign-ups in 70+ organisations in 30+ countries worldwide.

Doctors globally use Resuscitation VR as a compulsory curriculum module to train residents to diagnose and resolve emergency medicine events whilst in a high-pressure, simulated environment. These modules are also utilised for refresher and upskilling training, and alternatives to resource-intensive traditional patient actor or manikin-based simulations.

Resuscitation VR modules are scalable, which means that additional procedures can be designed and developed using the same technological framework—including localisation to international standards, terminologies, and practices. The module library is regularly growing to include more critical care scenarios and localised content supported by this framework, and clinical partners can utilise a co-production design framework for bespoke modules at low cost.

Fig. 1 In-application views of Resuscitation VR

3 Project Details

3.1 Challenge

Resuscitations are high-stakes, low-frequency healthcare events that are frequently and traditionally trained through manikin-based simulations. These scenarios include critical situations ranging from neurological emergencies to cardiopulmonary arrest and are known to be a source of significant mental load.

Much of the stress experienced by a "code lead" physician comes from the need for rapid information processing, situational awareness, and decision-making, rather than in the physical tasks, which are left to other team members.

Due to the high risk of negative patient outcomes, resident physicians are not typically expected to manage resuscitation events, despite a theoretical knowledge of resuscitation procedure—but staffing and circumstance means that they are sometimes placed in this role and responsibility in early clinical practice. Therefore, the first real-life resuscitation event a resident manages is a pivotal career moment that cannot be fully trained for with traditional simulations.

The challenge that critical care units (CCUs) face is giving residents a safe environment that replicates high-stress scenarios and reduces the dependency on manikin-based training, which is expensive and requires the presence of multiple senior medical professionals.

Virtual reality has the capacity to close this gap: to provide a high level of audio-visual immersion and faithfully replicate the real environment, tools, and persons, without the same high resource requirements.

3.2 Solution

Resuscitation VR is split into scenario modules that each focus on a particular type of high-risk patient or emergency. Each module places the user as the "code lead" physician in the room, who must make quick decisions and perform tests to diagnose and stabilise the patient.

The virtual clinical environments are designed to be realistically immersive, not only having the same appearance and layout as a real-world emergency room—originally the genuine resuscitation room at Children's Hospital Los Angeles—but also with an authentic soundscape of hospital noises and alerts.

All scenarios use branched-chain algorithms to alter the virtual patient's physiology beneficially or adversely depending on the user's actions and decisions. Hand-held controllers allow the user to select appropriate physical examinations, treatment options, and staff commands.

As well as offering a safe place to practise, Resuscitation VR also captures rich data—for example, actions, stimuli, decisions—about each user performance, which is then transcribed into personalised scenario feedback and scoring. The primary queries for such feedback are provided by clinical partners during scenario design, but the performance recordings are formatted in such a way to also allow for additional queries to be added via simple filters, including retroactively on past performances.

As the patient and symptoms vary between modules, so too do the medications and tools available, and most crucially, the steps required to revolve the emergency event. Scenarios also have variations, or "difficulties", that challenge the learners to build upon their knowledge and skills to complete the same base scenarios but with additional problems and complications introduced. Beginner modes offer simpler problems and helpful suggestions from staff, whereas in advanced modes the standard protocol may not be effective and the characters around the lead physician will be much more stressed and less patient with mistakes.

Similarly, the Resuscitation VR scenarios offer "distraction" levels, which code the frequency and intensity of external stressors introduced to the learners—for example, evocative language and noise levels. This design caters to strengthening trainees' stress management skills simultaneously with their clinical skills.

3.3 Benefits

This design of engaging learners at the boundaries of their knowledge and skill is the *desirable difficulties* (Bjork & Bjork, 2011) fundamentally

found within *deliberate practice* (Anders Ericsson, 2008). Learners engage not with isolated simulation sessions but instead with purposeful and guided training aided both by the escalations within the scenarios themselves and with the specific, targeted feedback for improvement and reflection.

Core learning design behind Resuscitation VR is of experiential learning (Fromm et al., 2021), in which learners get hands-on experience and guided reflections and debriefing on learning. This is the closet virtual equivalent to genuine real-world experience and has high skill transfer and knowledge-retention outcomes.

Additionally, the underlying system design caters for both *self-guided learning* (in which the trainee guides their own learning) and *peer-to-peer learning* (in which trainees guide each other), alongside traditional instructor learning, to increase simulation training frequency and enhance training outcomes (Minocha et al., 2017).

4 Feedback from End Users

Resuscitation VR modules have been validated in multiple studies by doctors and medical staff (Fig. 2).

The first two modules developed for Resuscitation VR are the focus of the subsequent studies referenced in this chapter. These two studies focus on paediatric emergency (infant status epilepticus and paediatric anaphylactic shock) and were developed in collaboration with Children's Hospital Los Angeles. Both scenarios had significant airway, breathing, or circulation problems that matched an emergency severity index (ESI) 1 or 2 resuscitation. After the success of the two paediatric modules, a series of additional paediatric and adult modules were commissioned and produced.

4.1 Initial Pilot

After a published study evaluating the use of Resuscitation VR alongside real-world resuscitation events (Chang et al., 2019), Resuscitation VR

Fig. 2 Resuscitation VR in use

was formally rolled out in April 2019 and has been adopted as a mandatory curriculum material for clinical staff in critical care units (CCUs).

This study found that Resuscitation VR could be most beneficial for residents—in comparison to senior physicians, who had lower stress levels overall across both VR and real-world resuscitations—as early-stage clinicians reached a potential "optimal stress" level whilst using the simulation, which could increase engagement and skill retention.

Doctors have found it to be more cost-effective than manikin-based training which makes it scalable and builds a business case for easy adoption across CCUs. Kathyryn Schaivone, certified simulation educator at Kaiser Permanente Hospital, said, "Currently we are only able to run critical events such as paediatric resuscitation training two to four times per year since we cannot take our teams away from patient care more frequently. VR levels the playing field in a way that doesn't happen with in-person methods and provides the flexibility for more frequent participant in simulation."

Further, "a limitation of many outpatient offices and care centers is lack of space for simulation rooms and simulation centers," explains principal researcher on the project Dr. Josh Sherman, "using Oculus for our VR modules will allow for on-the-spot training without the need for extra real estate."

4.2 Stress Inoculation

These findings were confirmed with a follow-up study (Chang et al., 2020) which similarly found "providing novice learners with simulations

that approximate real resuscitations could have potential as stress inoculation" using experiential exposure therapy training concepts.

This study also discussed the value proposition of using VR in simulation centres for training, including "asynchrony—the ability to conduct the simulation any time without a real-time facilitator" and that "VR can provide a suitable complement when physical simulations are less easily transported or delivered".

It also outlined some limitations of standard VR control schemes with seasoned attendings, and novice VR users, which prompted a follow-up study on usability.

4.3 User Experience

To explore this further, a study was conducted on the common user experience in VR healthcare simulations (Matthews et al., 2020), which found a correlation between user errors and novices using a hand-held controller interface, incurring barriers with the *gulf of execution* (Norman, 2013), as well as design considerations for the limited *possibility space* (Bogost, 2008) inherent to virtual simulations.

These findings and recommendations of interaction designs lead into "New Ways to Interact" explored in "Future Outlook".

4.4 Comparison with Manikin-Based Simulation

Finally, a study by Abulfaraj et al. (2021) compared learner performance in the Resuscitation VR simulation vs. high-fidelity manikin-based simulations in a randomised trial.

The study found similar learning outcomes across both the manikin-based control and the Resuscitation VR intervention groups, as well as a high overall satisfaction score showing that it was easy to use and could increase intention to use if available. This finding supports Resuscitation VR as a highly beneficial curriculum tool to supplement traditional simulation training tools and improve simulation training capabilities.

5 Future Outlook

Prompted by these research studies and ongoing needs of clinical partners, there are a number of ongoing innovations being produced for Resuscitation VR.

5.1 New Ways to Interact

Focusing on closing the "*gap of execution*" as outlined in Matthews et al. (2020), hand-tracking controls and intelligent voice recognition systems are being demoed and integrated in all Resuscitation VR modules, to be concluded and launched in 2022.

To support this, a usability thesis is underway to investigate human-centred design advancements for both Resuscitation VR and immersive healthcare simulations in general. It is hoped that this research will strengthen the discipline with standardised design practices and interaction principles.

5.2 New Ways to Build

One identified barrier limiting the wide adoption of immersive simulations is the high technical cost required for new content and scenario customisation (Baniasadi et al., 2020). This is being addressed as part of the Resuscitation VR toolkit in two ways:

Firstly, in partnership with the University of Mississippi Medical Center, an immersive teaching interface is being developed to allow simulation trainers to modify environments, patients, tools, and various other parameters, both in preparation for a simulation training session to meet the learning material, but also live during the simulation session in response to learners' actions and behaviours. This functionality adapts the flexibility of high-fidelity manikin-based simulations and patient actors into the virtual domain.

Secondly, framework development using state-of-the-art AI is underway to allow clinicians and subject experts to design entire modules

themselves, without technical knowledge required, using an immersive intuitive interface.

Both of these tools are planned for launch in 2022 and will be formally announced in the coming months.

6 Conclusion

Resuscitation VR is a proven simulation platform for emergency medicine training, implemented in collaboration with medical experts and supported by robust studies. The software can be used to supplement and/or replace traditional manikin-based simulations at a lower upfront and running cost and has the additional benefits of soft skills gain and persistent learning support supported by pedagogy and research.

As the XR ecosystem grows and new possibilities are afforded, so too will Resuscitation VR to meet the training needs of each new cohort of clinicians.

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