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**Article title**

Use of a Virtual Reality device for basic life support training; prototype testing and an exploration of users’ views and experience

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**Abstract**

Introduction

Immediate initiation of cardiopulmonary resuscitation significantly increases the chances of survival after a cardiac arrest. Virtual reality devices allow the integration of features of real patients into training to facilitate interaction and feedback, thus improving performance. However, its use as a training tool remains under explored. The aim of this study was to undertake initial testing of a virtual reality basic life support prototype and to explore users’ views and experiences.

Methods

We recruited 23 adult staff members working at a Central London University in England and exposed them to a five-minute virtual reality experience. Each participant completed a pre and post questionnaire and took part in a focus group discussion. Quantitative data were descriptively analyzed whilst qualitative data underwent thematic analysis.

Results

Regardless of prior experience of using virtual reality and/or performing basic life support, most participants scored >90% for chest compressions and reported an increase in confidence and competence post experience. Focus group discussions identified four key themes: experience and expectations; performance and feedback; interaction and immersion; potential.

Conclusion

Our study suggests virtual reality is an enjoyable method by which to teach basic life support. Although concerns over the accuracy of the tracking system and the small sample size weaken our conclusions regarding its ability to assess performance, our exploratory data are of value to educators, researchers and policy makers. Future work needs to address our study limitations, consider how virtual reality fits into the broader context of training and attend to accreditation and resource issues.

**Keywords**

Virtual reality; resuscitation; healthcare; focus groups; survey; simulation

**Introduction**

There are approximately 60,000 cases of adult cardiac arrest in the United Kingdom (UK) every year.[1] Immediate initiation of cardiopulmonary resuscitation (CPR) significantly increases the chances of survival and after calling for help, effectively performing chest compressions is the next most important intervention. [1,2,3] International recommendations for adults are to perform chest compressions with minimal interruptions at a rate of 100–120 min with a depth of 5-6cm, allowing complete recoil of the chest after each compression. [1,2,3] The Resuscitation Council (UK) recommend that all adults and children are taught CPR; that training should prioritize achieving effective compressions and that, wherever possible, feedback and prompts should be integrated into training.[1]

Virtual reality (VR) devices allow the integration of features of real patients into training to facilitate interaction and feedback, thus improving performance. [4,5] As an adjuvant-training tool, VR has demonstrated ability to enhance learning and skill acquisition [6,7] in a number of different areas of healthcare, including dentistry and surgery. In an evaluation of a VR device for resuscitation training specifically, Semeraro et al. reported a positive overall evaluation.[5] An international survey further supports the potential importance of VR for resuscitation training. [8] Its value for teaching basic life support (BLS), however, remains under explored.

The aim of this study was to undertake initial testing of a VR prototype designed to teach BLS and to explore users’ views and experiences. Objectives were to: 1. Assess how well those using VR (with and without prior training) can perform chest compressions and 2. Explore users’ views, perceptions and experiences of using VR for BLS training.

**Methods**

This mixed methods study was conducted at a central London University in England, with ethical approval granted by the University (UEP0817).We recruited 23 adult (>18 years) staff members from a range of departments (Table 1). Ten declared previous resuscitation training (trained) whilst 13 stated no training since at least 2015 (not trained).

Insert Table 1 here: Sample characteristics

We exposed participants to a single standardized five-minute VR experience called Code Blue. Code blue uses VR in combination with physical objects for tactile feedback. This differs from augmented reality as the user is still in the present world and does not wear VR goggles [9]. The Code Blue application (app) works using a computer, an HTC Corporation Vive headset and trackers attached to the wrists of the user (which relay movement and position back to the computer) and a low-end physical mannequin (see figure 1). The Code Blue prototype has previously undergone testing by users at exhibitions, but not been subjected to any formal evaluation.

Insert Figure 1: VR in progress

Insert Figure 2 here: Participant view

Following a short teaching module delivered via the VR system, users experience a simulated emergency, which requires completion of six steps (Table 2). Guidelines set by the UK Resuscitation Council [1] were the gold standard, against which performance was assessed using wrist tracking technology.

Insert Table 2 here: Six steps of VR experience

Participants completed two anonymized paper-based questionnaires; questionnaire A immediately prior to the VR experience and questionnaire B, on which their performance score was recorded, immediately afterwards. Based on a previous tool,[5] the questionnaire used a 7-point Likert scale[10] to establish participants’ feelings before and after the VR experience, previous experiences with VR and perceptions regarding the extent of its user-friendliness, realism, and interaction/immersion. Using a range from 1 (completely disagree) to 7 (completely agree), participants were asked to state the degree to which they agreed with a number of statements.

Following best practice guidance, [11] two audio-recorded focus group discussions took place the day after the VR experience; one for those who had received resuscitation training since 2015, when the guidelines were last updated (trained) and one for those with no recent training (untrained).

Data analysis

Questionnaire data are reported descriptively using raw numbers, percentages and averages. Anonymized and transcribed qualitative focus group data underwent a standard process of inductive thematic analysis. [12] All three researchers independently performed initial coding of the data. A consensus approach enabled agreement of final themes and the identification of common insights from which recommendations were determined.

**Results**

Data analysis was limited to descriptive statistics. Questionnaire responses reflected that most were looking forward to and subsequently enjoyed the VR experience (Table 3). Prior to the experience, participants in the ‘trained’ group reported less confidence in using VR than those in the ‘untrained’ group (average score 2 vs 6), however, their confidence was matched post experience (Table 3). Perceptions of competence in the ability to perform BLS by participants in the ‘untrained’ group also improved after the VR experience (Table 3).

Insert Table 3 here: Feelings about the VR experience

Table 4 details participants’ performance scores. Whilst most (*n*=15, 65%) scored >90%, two people (9%) scored 55% or less, due to a compression rate slower than the recommended practice. The performance of those with recent resuscitation training was better overall. However, eight (62%) of the participants in the ‘untrained’ group scored 90%. Most participants (*n*=18, 78%) strongly agreed that they perceived the score to be a true reflection of their performance (Table 3).

Insert Table 4 here: Chest compression performance scores

Table 5 details reported levels of user friendliness, realism and immersion. Participants agreed that the information given at the start of the experience was useful and clear (*n*=20, 87%) and that the equipment was comfortable and easy to put on (*n*=21, 91%). Participants (particularly those in the ‘trained’ group) were, however, less likely to agree (score >5) that it was easy to place the call and perform chest compressions (*n*=11, 48%). Most (*n*=17, 74%) agreed that the scenario and the environment were realistic, although fewer people in the ‘untrained’ group were convinced that classical signs of cardiac arrest were present (*n*=9, 69% vs *n*=9, 90%). Many participants, particularly those in the ‘trained’ group (*n*=7, 70%), agreed that the virtual hands were not realistic (score <5) and that it was difficult to reach and touch the patient (score ≥ 5).

Insert Table 5 here: User friendliness, realism and immersion

Focus Group findings

Table 6 details the final four themes and their subcategories, identified from an initial 28 codes. Because of the small sample size, we were unable to achieve data saturation.

Insert Table 6 here: Themes and codes

### Theme 1: Experience and expectations

Participants described enjoying the VR experience, with general agreement that the opportunity to practice compressions was the best component. One participant said: “*I felt this was my experience, not surrounded by other people, I’m not watching or being watched, which was good for me” (trained*). However, people also described feelings of discomfort: *“There’s a limit to how much VR I can take. After about ten minutes or so I start feeling sick” (untrained).*

Expectations and feelings were attributed to previous BLS training, the level of familiarity with VR and the context within which the simulation took place: “*I think that because I’d done it before [VR] it was slightly different. Less self-conscious every time because you’re more used to it” (untrained).* Discussions also reflected a view that as VR becomes more commonplace, it might be difficult to sustain the level of enjoyment.

### Theme 2: Performance and Feedback

Participants discussed the value of real time feedback, although people were not always aware of this happening.Feedback improved peoples’ confidence, with statements made such as “*much more confident at the end that I could definitely save someone’s life” (untrained).* However, one participant said: “*It bothers me that you would use it and then think that you were safe to be able to do CPR” (untrained).*

Participants considered both audio and visual feedback to be important: *“I’m a visual person rather than an auditory but need both of those things working together to score” (untrained).* Some really liked the visual information, but others felt unsure what the graphics were telling them: *“Then on the screen there was a green line and then there was a red line. I didn’t know what that red line was, I didn’t know what the green line was, so what’s the point of showing it up?” (trained).* Participants also pointed out the value of the auditory feedback, although there was some noted reluctance to believe the feedback.One participant, who was hearing impaired, further commented that the audio should, *“cater for people who are deaf…Just the opportunity to turn it louder would’ve been fine” (trained).* People also described inconsistencies in the information they received from different sources: *“I was being told really good compressions, really even, but then got quite a low score” (untrained).*

Participants described the introduction and recorded instructions as insufficient and unclear, resulting in people feeling unsure: *“I kept waiting for her to say that we’re going to start” (trained).* Insufficient information about how to check for safety and how to do compressions properly was also noted. Having the instructor in the corner of the screen was described as distracting: *“Because when I was trying to concentrate on the dummy and the visual representation in front of me, I’d sort of catch her waving her arms in front of me”* *(untrained*). Instead, participants wanted an opportunity to ask questions and to understand why they hadn’t performed as well as they might have: “*I did hear it or I saw uneven compressions but I didn’t know what they wanted me to do to adjust that. Was it because my hands were slightly in the wrong place? So that kind of feedback would’ve been really useful” (untrained).*

### Theme 3: Interaction and immersion

Participants described a sense of immersion, particularly while doing chest compressions: “*I didn’t think of anyone around me or anything like that because I was very much in the experience at that point” (untrained)*. However, there was also a desire for a more realistic environmental context: *“I felt like when you come across that situation it’s never going to be in a dark alley” (trained).*

Participants highlighted the importance of getting the initial set up right: *“It’s got a nicely positioned body which is just not going to happen” (trained).* They also pointed out missing details, which would have enhanced the reality: *“We were told to stop and let an ambulance arrive. I looked around for it and it wasn’t there” (trained).* Participants discussed the need for time to practice moving around the virtual world prior to starting the full simulation saying: *“… A bit like when you go onto a gaming consul, the opening screen is VR and so you can get used to it before you go into a game” (untrained).* Opportunities to progress to more difficult scenarios were also requested.

In general, participants thought the equipment comfortable to wear and felt it enabled sufficient interaction with the physical mannequin. However, one participant who wore glasses said: “*I had this scratchy piece of plastic just pressed up against my face” (trained).* Another participant also described how it had interfered with her ability to undertake the simulation exercise: “*I sort of fumbled my way through and got to the end but when it came off my glasses were all fogged up” (trained).* The wrist trackers had also hindered correct hand positioning for chest compressions: *“I couldn’t put them together because of the wrist bands…I mean I still got my hands in somewhat of a thing, but I had to keep them apart rather than how they should’ve been” (untrained).*

There was agreement that the virtual hands lacked reality: *“I couldn’t actually work out how to put my fingers …I couldn’t figure out how to do my own hands because on the screen the fingers don’t move” (trained).* The virtual hands also made it difficult for people to place the required phone call and participants’ conversations reflected the lack of perceived reality associated with the call itself:

*“M: Then that massive chunky phone [laughter] thing, where you’re trying to press the button on it. It worked but it just felt really….*

*M: There was no connection between the physical world and the virtual world.*

*M: And you didn’t put the phone down, did you? It just disappeared” (trained).*

Participants further discussed difficulties locating body parts: *“The virtual person was just like a very plain moulded shape that didn’t actually fit with what we were actually feeling” (trained).* There was also some lack of clarity about what needed to be achieved and participants described the scenario moving on without them completing required actions: *“I went to tilt the head back and then it just moved on” (untrained).*

To increase the sense of interaction, participants suggested the need for more sensors: *“If they can put some sensors on the actual mannequins’ heads so it matches in the virtual reality world because it wasn’t” (trained)* andthat the user wear gloves *“so you could actually have seen your hands positioning” (trained).*

### Theme 4: Potential

Participants acknowledged the wide-ranging potential of the VR prototype, with its flexibility considered to make it commercially very attractive: *“If you’ve got a mannequin and the product you could practice as often as you like, whenever you like, with whoever you like” (untrained).* Its potential to be cost saving in the longer-term was also pointed out: *“…we won’t need the techs to set it up; we won’t need the lecturers there; we just need one person, headset and gone” (trained).*

Participants discussed the future purpose of the prototype at length, expressing confusion over whether it was a tool to support learning, assessment or both*.* Participants agreed that it could be a valuable tool to support BLS teaching in schools: *“Getting kids to do CPR when it’s just a dummy at the front of the class isn’t anywhere as interesting as this. It’s almost like playing a game for them in a way” (untrained).* Industry was identified asanother potential target group*.* Those in the ‘trained’ group also talked about its potential for use with healthcare students, questioning how it fitted into the broader teaching package*.*

Participants suggested developing a wider range of different scenarios, relevant to different contexts: *“Lots of accidents happen all the time… It may be very powerful in an engineering company or if you work on an oil-rig” (untrained).* There were, however, concerns about how the information would remain up to date. Participants also discussed credibility and the need for professional accreditation: *“If you’re going to commercialise it then it can’t be just their company saying that this is the way to do things, it needs to have someone backing it up” (untrained).*

Discussion

Our questionnaire data suggest that VR (with and without prior training) may be an effective method with which to teach BLS, with most participants scoring >90% at the end of a five-minute period of training. There are two possible reasons for the unusually high percentage of scores above 90%; either the device really is superior to other available products or it lacks the ability to discriminate between high and low quality chest compressions. Accurate assessment of chest compression depth is a challenge commonly reported in the literature [15,16]. The designers of the Code Blue app report that the HTC Vive wrist tracker measurement of depth accuracy is up to 1mm, but no valid reference currently exists for this.

Perceptions of both confidence and competence improved for most, particularly related to chest compressions. Gurusamy et al (2008) argue that the movement of confidence post exposure is common although competence per se, less so. [6] Plessas (2017) suggests that the VR experience can be a less threatening form of training and can therefore enhance skill acquisition for those with and without prior experience of VR (as in the case of our study participants). [7] However, findings from the qualitative data highlight the potential for people to feel overconfident about their level of competence.

Although the small sample did not allow inferential statistical analysis, our preliminary data suggest that the prototype was user friendly, realistic and immersive. However, some aspects, such as the realism of the virtual hands and alignment with the physical mannequin require development. The environmental contexts presented and the degree to which they were realistic further affected people’s experiences. A sense of relevance and realism is an important component of effective interactive learning, [13] which if you get right can also encourage people to become more self-motivated learners.

The focus group discussions showed broad support for the use of VR for future BLS training, although not to fully replace conventional face-to-face training within a healthcare setting. Discussions also highlighted the need for people to be sufficiently prepared and supported during the VR experience and for further attention to be given to the sequencing, timing and response to participant actions.

In keeping with the findings of Semeraro et al. (2009, 2017), our data suggest that VR could be a useful addition to BLS training. [5,8] Indeed, the Resuscitation Council (UK) has already developed an interactive life-saving app ‘Lifesaver VR’ to teach people what to do when someone has a cardiac arrest (<http://lifesavervr.org.uk/>). There is, however, a need to clarify target groups and adjust the VR experience accordingly. For example, younger people’s familiarity with gaming and technology needs to be considered and VR contexts need to be adaptable to relevant social and/or work environments and to a user’s level of expertise. How to sustain the current ‘novelty’ factor also needs some thought. Furthermore, although recent developments make VR more affordable,[14] ongoing costs related to use of the prototype need consideration and, in line with the sector view [6] accreditation and quality assurance processes need attention. In particular, there is a need to consider the accuracy and precision of tracker systems used during VR to assess actual performance [15,16].

Limitations

Our small sample of volunteer participants all came from a single institution, with many employed within the health education sector. The sample size precluded inferential statistical analysis and the achievement of data saturation. In addition, some participants anecdotally reported a lack of initial briefing and preparation and on one occasion the app stopping working during the experience. These factors may have adversely affected some participants’ experience and subsequent reporting.

The performance score written on top of the form handed to participants as they left the room after the VR experience might have affected how they responded in the focus group. However, most commented that they had not noticed the score. There were also some contradictions between the questionnaire and focus group data. This, however, was expected given that open forums allow time for discussion and reflection, and hearing other peoples’ feedback can influence an individual’s initial views.[17,18]

Finally, there is some question over the accuracy and precision of the HTC Corporation Vive system, [19] which weakens any conclusions about its ability to assess compression performance. Despite these limitations, as an exploratory study evaluating the potential of VR, we believe our data are of value to the wider community.

Conclusion

The aim of this exploratory study was to undertake initial testing of a VR prototype designed to teach BLS and to explore users’ views and experiences. Although further work is required to provide users with confidence in the accuracy of the measurement system and to increase the sense of user-friendliness, realism and interaction, our findings suggest that VR is a potentially effective method with which to teach BLS. There is, however, space for further research as VR becomes more common within healthcare education.

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**Figures**

Figure 1: VR in progress

Figure 2: Participant view

**Tables**

Table 1: Sample characteristics

Table 2: Six steps of VR experience

Table 3: Feelings about the VR experience

Table 4: Chest compression performance scores

Table 5: User friendliness, realism and immersion

Table 6: Themes and codes