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Comparing bystander response to a sudden cardiac arrest using a virtual reality CPR training mobile app versus a standard CPR training mobile app

Marion Leary[a,b,*], Shaun K. McGovern[a,b], Zainab Chaudhary[a,b,c], Jaldhi Patel[a,b,c], Benjamin S. Abella[a], Audrey L. Blewer[a,c]

[a] Center for Resuscitation Science and Department of Emergency Medicine, Department of Emergency Medicine, University of Pennsylvania Perelman School of Medicine, United States
[b] School of Nursing, University of Pennsylvania, Philadelphia, PA, United States
[c] Department of Family Medicine and Community Health, Duke University, Durham, NC, United States

Abstract

Background: Using a mobile virtual reality (VR) platform to heighten realism for cardiopulmonary resuscitation (CPR) training has the potential to improve bystander response.

Objectives: We examined whether using a VR mobile application (mApp) for CPR training would improve bystander response compared with a standard mApp CPR training.

Methods: We randomized lay bystanders to either our intervention arm (VR mApp) or our control arm (mApp). During a post-intervention skills test, we collected bystander response data (call 911, perform CPR, ask for an automated external defibrillator (AED)), along with CPR quality (chest compression (CC) rate and depth). Wilcox rank sum was used to analyze CC rate and CC depth as they were not normally distributed; Pearson's Chi-square was used to analyze Chain of Survival variables.

Results: Between 3/2018 and 9/2018, 105 subjects were enrolled: 52 VR mApp and 53 mApp. Mean age was 46 ± 16 years, 34% were female, 59% were Black, and 17% were currently CPR trained (≤2 years).

Bystander response was significantly higher in the VR mApp arm: called 911 (82% vs 58%, p = 0.007) and asked for an AED (57% vs 28%, p = 0.003). However there was no difference in CPR performed (98% vs 98%, p = NS) and the application of the AED (90% vs 93%, p = NS). When comparing the VR mApp to the mApp, mean CC rate was 104 ± 42 cpm vs 112 ± 30 cpm (p = NS), and mean CC depth was 38 ± 15 mm vs 44 ± 13 mm (p = 0.05).

Conclusion: The use of the VR mApp significantly increased the likelihood of calling 911 and asking for an AED, however, CC depth was decreased.

Keywords: Cardiac arrest, Cardiopulmonary resuscitation, Virtual reality, Sudden death, Simulation, Bystander response, Chain of survival, Mobile app

Introduction

Cardiopulmonary resuscitation (CPR) training for sudden cardiac arrest (SCA) was established over 50 years ago.[1] Over that time span, the paradigm for bystander CPR training has remained largely unchanged — in a classroom setting and using a plastic manikin. One concern with this type of CPR training is the lack of realism that a bystander would experience during an actual sudden cardiac arrest (SCA) event.[2–5] Therefore, resuscitation science organizations such

* Corresponding author at: University of Pennsylvania, School of Nursing, Philadelphia, PA, 19104, United States.
E-mail address: mleary@nursing.upenn.edu (M. Leary).

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as the American Heart Association (AHA) have thus called for innovative solutions to increasing public CPR training rates using digital strategies such as virtual reality (VR) and mobile applications (mApps).[6]

Digital strategies, including mApps and wearable devices, have advanced rapidly allowing greater dissemination of these technologies. In a recent report on SCA, the National Academy of Medicine acknowledged that, “innovation in smartphone and mobile applications . . . could significantly reduce the time interval between collapse and treatment and substantially improve patient survival rates.”[7] The AHA released a scientific statement focusing on the use of Mobile Devices to Improve Emergency Cardiovascular Care; the statement concluded that new digital initiatives should be an area of high research priority.[8] Thus, focusing on new technologies, such as VR, to improve CPR training and dissemination represents an important area for innovation over the standard CPR training approach.

Though the addition of hands-only CPR for lay providers has increased the dissemination of CPR training further into the public domain, bystander response is still low relative to the incidence. Therefore, other innovative solutions need to be considered for lay person CPR training.[9] Thus, we sought to compare an established hands-only CPR training video app with a novel mobile VR CPR training app for lay bystanders in local community settings. As VR allows for the creation of multisensory scenarios that heighten stress and realism, our hypothesis is that the addition of the VR component would allow for trainees to acquire improved bystander response metrics and skill for performing CPR.

Methods

Study design

We conducted a randomized controlled trial of digital CPR training comparing our VR CPR training mApp with our established CPR training mApp without VR. The VR mApp integrated a smartphone with a VR cardboard viewer for multisensory immersion. Both the VR mApp and our established mApp included hands-only CPR instruction. The standard mobile application for hands-only CPR training has been validated and used in previous studies investigating video-only training methods.[10] The VR mApp scenario was created based on our mApp video created for a previous study (Fig. 1). Subjects randomized to the standard mApp were given the opportunity to experience the VR mApp following the completion of the skills check and post-survey. This study was reviewed and approved by the University of Pennsylvania’s Institutional Review Board.

Study participants

Subjects were recruited from public locations (i.e. libraries, transit stations, health fairs etc.) within one urban city and were randomized to our intervention arm (VR mApp) or our control arm (mApp). We enrolled a convenience sample of adults (≥18 years). Subjects in the VR mApp arm underwent CPR training and were able to interact with avatar bystanders, “perform” CPR via VR viewer click button, and

Fig. 1 – Screenshot of the VR mApp and scenario; screenshot of the mApp and video.

acquire an AED in the virtual environment. The standard mApp arm underwent our established video-only CPR training modified from the AHA's family and friends CPR training video but did not have the VR immersion. We collected bystander response data (call 911, perform CPR, ask for an AED), along with CPR quality data (chest compression (CC) rate and CC depth) during a 2-min post-intervention scenario. A subset of subjects participated in a qualitative interview that will be reported in a separate manuscript.

Digital strategies

CPR mApp. Our standard CPR mApp video was created for a separate project examining video-only CPR, published previously, and modified based on the AHA's Family and Friends CPR training video. Subjects donned headphones and were given a smartphone (Samsung S7) with the mApp preloaded. Subjects were instructed to watch the approximately 4.5-min hands-only CPR instructional video produced by our team and based on 2015 AHA guidelines.[11] This video included hands-only CPR training and audio instructions for use of an AED, though the application of an AED onto a manikin was not shown. Instructions on checking for responsiveness, calling emergency medical services, performing CPR and using an AED were included in the video. After watching the in-app video, subjects performed the skills check, and then all subjects were debriefed and any missed steps in the sequence of resuscitation actions were reviewed.

VR mApp. Our VR mApp was created based on the established CPR mApp training video including similar language and audio and video instructions regarding checking for responsiveness, calling emergency medical services, performing CPR and using an AED. Subjects in the VR mApp arm were able to interact with the virtual scenario and able to perform tasks such as applying the AED, as opposed to the mApp arm that passively watched a video. Subjects in the VR mApp arm donned headphones and a cardboard VR viewer paired with the same smartphone (Samsung S7) as used in the mApp arm. Subjects were oriented to the device by the study team. Subjects were prompted to view an approximately 4.5-min tutorial scenario and instructed to follow all in-application prompts. Following the tutorial scenario, subjects were encouraged to react to an in-application cardiac arrest simulation; subjects had the option to prompt a bystander to call 911, retrieve the AED, and perform chest compressions using an input button on the top of the cardboard VR viewer. At the completion of the simulation, VR mApp subjects received a scorecard, ranging from 0 to 5 hearts, based upon their performance including activation of 911, use of AED, and quality of compression rate as set by 2015 AHA guidelines.[11] After the completion of the VR mApp subjects also performed a skills check, were debriefed, and their resuscitation actions were reviewed.

Data collection

Survey data were collected from all participants pre- and post-intervention. Pre-survey variables included age, gender, race, zip code, closest major intersection to home, education level, yearly household income, employment status, and questions related to knowledge of CPR, AED, and chain of survival (Supplemental Appendix). Subjects in both the VR mApp training and the standard mApp were asked to complete an additional survey post-intervention which queried the lay providers regarding their motivation to attain CPR training and their perspectives about using VR technology for CPR training (Supplemental Appendix).

Post-test scenario

After subjects completed either the VR mApp or the standard mApp hands-only CPR training they were asked to complete a 2-min skills check. The scenario was performed on a CPR recording manikin (ResusciAnne, Laerdal Medical, Wappinger Falls, NY) which collected CPR quality data (CC rate, CC depth, no-flow time etc.). Subjects were shown the high-fidelity manikin placed on the ground in the supine position. Subjects were asked to imagine the manikin was a real person and given the prompt, “This person has just collapsed. They are unresponsive and not breathing. Go through all of the steps you would do in real-life. Rely on the training that you just received.” Variables recorded and documented by research staff during skills check included bystander response (noticed SCA, interpreted SCA as a problem, took responsibility for dealing with SCA, and possessed skills for dealing with SCA), chain of survival metrics (recognize SCA, activated 911, performed CPR, requested AED, used AED), and CPR quality (e.g. mean CC depth, mean CC rate). At the completion of the 2-min skills check subjects were debriefed on steps of the chain of survival, quality of CPR, and encouraged to ask any questions they may have about resuscitation. Subjects then completed a post-survey with questions relating to VR, the sequence of bystander response actions, and CPR.

Statistical analysis

Bystander response data (call 911, perform CPR, ask for an AED), along with CPR quality (chest compression (CC) rate of 100–120 CC per minute and CC depth of at least 2 in.) were collected during the 2-min post-intervention scenario and skills test. Chain of Survival variables (call 911, perform CPR, use AED) were quantified as binary (yes/no) variables analyzed using Pearson's Chi-square; CC rate and CC depth were analyzed using Wilcoxon rank sum as they were not normally distributed.

Results

Between March 2018 and September 2018, 105 subjects were enrolled: 52 VR mApp and 53 mApp. Mean age was 46 ± 16 years, 34% were female, 59% were Black, and 17% were currently CPR trained ($\leq$2 years). Additionally, 63 (63%) had $\leq$ some college, 19 (19%) had a Bachelor's degree, and 19 (19%) had a Graduate degree or higher. Overall, of those who reported, 72/96 (75%) had an annual income of $\leq$\$49,999 (Table 1). There were no significant differences between subjects randomized to the VR mApp compared with the standard CPR mApp with the exception of current CPR training and AED knowledge; subjects in the mApp arm were more likely to be currently CPR trained ($\leq$2 years) and know how to use an AED. (Table 1).

Bystander response

Of the 105 subjects enrolled, data from 101 subjects were analyzed (Fig. 2). One subject in the VR mApp arm could not done the VR headset and 3 subjects in the mApp arm were unable to complete the skills check. In total, 71/101 (70%) of all subjects called 911, 99/101 (98%) performed CPR, 43/101 (43%) asked for an AED and 39/

Table 1 – Subject demographics by cohort (VR mApp compared with standard CPR mApp).

	Total	VR mApp	Standard CPR mApp	p-Value
n =	105	52	53	–
Age (yrs), mean ± SD	46 ± 16	46 ± 16	45 ± 05	NS
Gender, n (%)		n = 52	n = 53	NS
Female	37 (34)	17 (33)	19 (36)	
Male	68 (66)	34 (65)	34 (64)	
Race, n (%)		n = 52	n = 53	NS
Black	62 (59)	30 (56)	32 (60)	
Other	19 (18)	10 (19)	9 (17)	
White	24 (23)	12 (23)	12 (23)	
Education, n (%)		n = 49	n = 52	NS
≤Some college	62 (62)	32 (65)	31 (60)	
Bachelors	19 (19)	9 (18)	10 (19)	
Graduate	19 (19)	8 (16)	11 (21)	
Annual income, n (%)		n = 47	n = 49	NS
<$20,000	42 (44)	2 (4)	1 (2)	
$20,000–$34,999	11 (12)	7 (15)	4 (8)	
$35,000–$49,999	19 (20)	7 (15)	12 (25)	
$50,000–$74,999	14 (15)	6 (13)	8 (16)	
$75,000–$99,999	4 (4)	3 (6)	1 (2)	
$100,000–$149,999	2 (2)	1 (2)	1 (2)	
$150,000–$199,999	1 (1)	0 (0)	1 (2)	
≥$200,000	3 (3)	2 (4)	1 (2)	
Current CPR training	15 (17)	n = 51	n = 52	0.004
(≤2 years), n (%)		3 (6)	14 (27)	
Know how to use an AED, n (%)	16 (18)	n = 51	n = 52	0.003
		3 (6)	16 (31)	

43 (91%) used the AED. Where comparing the VR mApp to the standard CPR mApp, the percentage of bystanders who responded according to the Chain of Survival was significantly higher in the VR mApp arm compared with the mApp arm for: called 911 42/51 (82%) vs 29/50 (58%), p = 0.007), asked for an AED (29/51 (57%) vs 14/50 (28%), p = 0.003); There was no difference for initiation of CPR (50/51 (98%) vs 49/50 (98%), p = NS) and use of an AED (26/29 (90%) vs 13/14 (93%), p = NS; Fig. 3). During the scenario, 101/101 (100%) of subjects noticed the SCA event, 100 (99%) interpreted it as a problem, 100 (99%) took responsibility for dealing with the SCA event, and 94 (93%) possessed the skills for dealing with the SCA.

CPR quality

Overall CPR quality data were captured on 99/101 (98%) subjects. Of those, 99/99 (100%) subjects performed CPR, the mean CC rate was 108 ± 36 compressions per minute (cpm), mean CC depth was 41 ± 14 mm. When comparing the VR mApp (n = 49) arm to the mApp

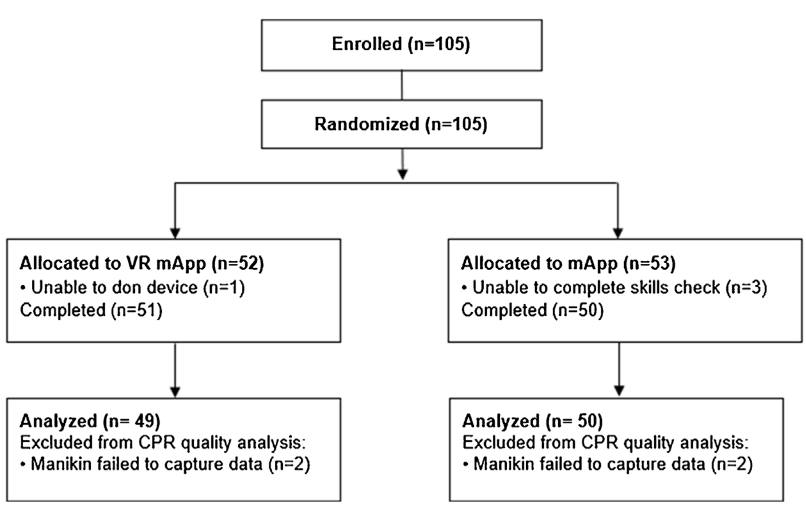

Fig. 2 – CONSORT diagram.

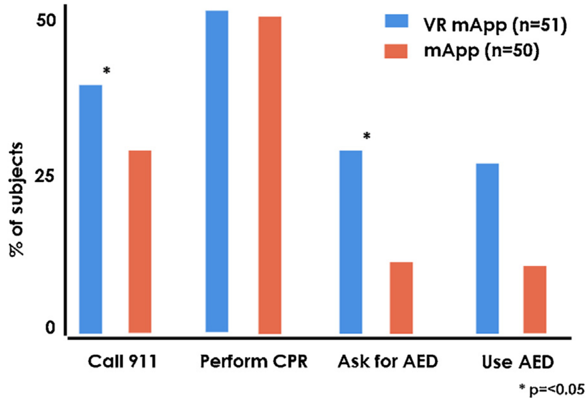

Fig. 3 – VR m App Chain of survival response compared with mApp.

(n = 50) arm, mean CC rate was 104 ± 42 cpm vs 112 ± 30 cpm (p = NS), and mean CC depth was 38 ± 15 mm vs 44 ± 13 mm (p = 0.05), respectively (Fig. 4).

Pre-survey

Prior to the start of the study subjects were asked to complete a pre-survey including demographic characteristics (age, gender, race, education, CPR training etc). Subjects were asked about their knowledge regarding the links in the Chain of Survival for SCA and their comfort with noticing an emergency, interpreting it as a problem, possessing the skills to respond, and feeling a responsibility to deal with the situation. Overall, 60/105 (57%) knew to call 911 for an SCA, 55/105 (52%) knew to perform CPR, and 34/105 (32%) knew to use an AED; 35/105 (33%) stated they did not know the steps in the Chain of Survival. There was no difference between the VR mApp and standard mApp cohorts (data not shown).

When queried regarding their perceptions of the stages of bystander response, overall 70/104 (68%) felt confident or very confident that they would notice an SCA event, 69/104 (67%) felt confident or very confident that they would interpret it as a problem, 68/104 (67%) felt confident or very confident that they would feel responsible for dealing with the event, and 54/104 (52%) felt as though they possessed the skills to act. Again, there was no difference between the VR mApp and standard mApp cohorts (data not shown).

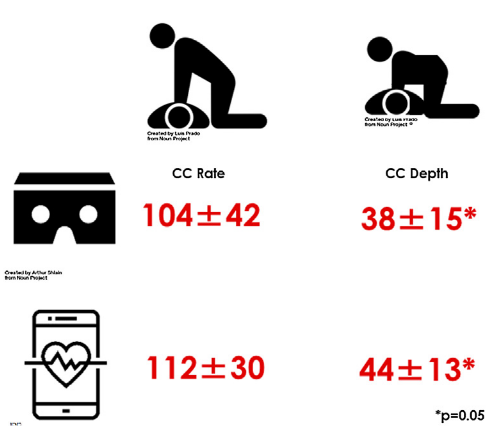

Fig. 4 – CPR Quality based on randomization of VR mApp versus mApp.

Post-survey

After completion of the study, subjects completed a post-survey regarding their actions during the post-intervention scenario and thoughts regarding the use of the VR technology for CPR training. Overall, 97/101 (96%) knew to call 911, 93/99 (94%) knew to perform CPR, and 72/101 (71%) knew to use the AED. Of those in the VR mApp arm, 47/49 (96%) knew to call 911 compared with 50/52 (96%) in the mApp arm (p = NS), 45/49 (94%) in the VR mApp arm compared with 48/51 (94%) knew to perform CPR (p = NS), and 41/49 (84%) of the VR mApp arm knew to use an AED, compared with 31/52 (60%) in the mApp arm (p = 0.05).

Of those in the VR mApp arm, 40/55 (73%) were comfortable or very comfortable using the VR device and 42/57 (74%) felt that the VR environment was realistic.

Discussion

In our randomized controlled study of two different digital CPR training modalities, we found that a VR mApp improved the bystander response metrics for calling 911 and asking for, and using, an AED compared with a standard video-only mApp. However, when examining CPR quality, the CC depth was significantly decreased in the VR mApp arm.

Despite longstanding education efforts, work from our group has found that only 18% of the US population is currently CPR trained[12–14] As has been noted in previous work, there exists a number of barriers for layperson CPR training.[15,16] Therefore, the AHA has called for enhanced efforts to train the public in bystander CPR using digital strategies such as mApps and VR.[6,8] Digital strategies including mApps and wearable devices have increased in capability and affordability allowing for greater dissemination of these technologies for use in healthcare training and education. The last few years have seen explosive growth in the domain of mobile technology to improve health education.[17–21] Per a Pew Research Center report, over 75% of Americans own a smartphone.[19] In addition, in 2017 there was an increase in smartphone use by lower-income individuals and those aged 50+ (up 12-points from 2015 to 44% and 58%, respectively).[19] In addition, studies have found that mobile health interventions may improve health behaviors, disease management, and training, including CPR.[22,23] As the landscape of healthcare continues to change at a rapid pace, VR has the potential to both disrupt current healthcare training paradigms and dissemination methods of life saving interventions to the public. A recent study highlighted the gaps related to healthcare providers' CPR training that could be enhanced by the use of VR. This study called for further targeted research into the use of VR for CPR education.[24] In addition to the potential for greater dissemination of CPR training, the cardboard VR viewers integrated with smartphones are a low-cost way to increase access to immersive technologies.

In our study we found that the bystander response metrics were higher in the VR arm compared with the standard mApp arm, this could be due to the high-realism that VR allows, fully immersing the trainee in the SCA scenario. Other studies comparing VR versus traditional trainings have found the addition of VR to improve training outcomes.[25–28] A recent study which also examined the use of VR for CPR training found that training subjects with VR improved knowledge and CPR skills.[25]

One study which examined training for pedicle screw placement found that surgical graduate students in the VR cohort performed better for accuracy and success rate of placement than the students in the standard training cohort.[26] Another study examining a VR learning environment compared with a 2D learning interface did not show a difference in learning outcomes with VR, however participants did perceive a learning advantage in the VR group.[27] It should be noted that both of those studies were performed using immersive VR compared with a mobile VR viewer.

In addition, we found that CC depth was significantly decreased in the VR mApp arm, this could be due to the fact that subjects could click the input button on the VR viewer for the CC rate but were unable to perform a similar action for depth. In addition, as subjects in the VR mApp arm were significantly less likely to be currently trained in CPR, this could have contributed to the difference in CC depth. As the CC rate was similar between both cohorts though, the tactile response of clicking at the appropriate CC rate may have provided no benefit. Another study using a mobile VR application to train students in the UK found that CPR metrics were comparable to face-to-face CPR training, though the authors suggested that the “true benefit” may be as an adjunct to the face-to-face training.[29] As we saw a decrease in depth, using VR in addition to an instructor lead training could assist with these potential deficits in CPR quality, though more research needs to be performed.[29]

There are a number of limitations inherent with our study. Though the VR mApp was created based off of our existing standard mApp for CPR training, the two applications were not identical. Therefore, certain aspects of the links in the chain of survival and CPR quality could have been inadvertently emphasized in one more so than in the other. Though AED instructions were mentioned in both mApps, the VR mApp allowed the subject to visualize AED application onto a virtual victim, which was not available to the mApp arm. Additionally, though there were significant differences seen in response during the post-test simulation, whether these actions would occur during a real-life cardiac arrest response is unknown. Finally, “cyber sickness”, also known as “VR motion sickness”, can occur when a user is in an immersive VR environment and can cause nausea and other motion sickness symptoms. It is possible that cyber sickness could have affected the performance of subjects in the VR arm, however, no subject reported any issues related to cyber sickness to our research team.[30]

The use of our VR mApp increased public interest in CPR training as evidenced by the number of subjects in the mApp arm committed to additional time with our team to experience the VR mApp (38%). The interest was enhanced by the subjects getting an opportunity to experience a novel technology that is largely out of the reach of many individuals. As has been noted, CPR training uptake is generally low, therefore, generating interest in acquiring CPR training with the use of VR, has large potential to increase training rates. The resuscitation community would benefit by implementing novel technologies such as VR and augmented reality (AR) into future training modalities to incentivize laypersons to acquire CPR training.

Conclusions

In our study comparing a VR mApp versus a standard mApp for CPR training, bystander response for calling 911 and asking for an AED was significantly increased with the addition of VR, however, CC depth was significantly decreased. Further studies will need to be powered to detect difference using immersive VR trainings and their effect on bystander response for sudden cardiac arrest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resuscitation.2019.04.017.

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