

Original Article

Observing the stages of bystander intervention in virtual reality simulation

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BACKGROUND: Understanding bystander reactions to an emergency is an important component of effective training. Four stages of bystander intervention (BI) have been previously described: noticing the situation as a problem, interpreting when it is appropriate to intervene, recognizing personal responsibility to intervene, and knowing how to intervene. Using virtual reality (VR) to simulate emergencies such as sudden cardiac arrest (SCA) can be used to study these stages.

METHODS: In a secondary analysis of an observational cohort study, we analyzed bystander self-efficacy for stages of BI before and after simulated SCA. Each subject participated in a single-player, immersive, VR SCA scenario. Subjects interacted with simulated bystanders through voice commands ("call 911", "get an AED"). Actions taken in scenario, like performing CPR, were documented. Scenario BI actions were compared based on dichotomized comfort/discomfort.

RESULTS: From June 2016 to June 2017, 119 subjects participated. Average age was 37±14 years, 44% were female and 46% reported CPR training within 2 years. During the scenario, 98% "noticed the event" and "interpreted it as a problem", 78% "took responsibility", and 54% "possessed the necessary skills". Self-efficacy increased from pre- to post-scenario: noticing the event increased from 80% to 96%; interpreting as a problem increased from 86% to 97%; taking responsibility increased from 56% to 93%; possessing necessary skills increased from 47% to 63% ($P<0.001$).

CONCLUSION: Self-efficacy to respond to an SCA event increased pre- to post-scenario. Bystanders who reported feeling comfortable "taking responsibility to intervene" during an emergency were more likely to take action during a simulated emergency.

KEY WORDS: Virtual reality; Bystander intervention; Emergency preparedness

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INTRODUCTION

When faced with an emergency, bystanders can react in a variety of ways; from ineffective panic, to calm and composed action, to frozen inaction.^[1,2] When a bystander witnesses an event, the transition from inaction to possible action includes four stages: noticing the potentially problematic situation, interpreting when it is appropriate to intervene, recognizing personal responsibility to intervene, and knowing how to intervene.^[3,4] These stages, known as the stages of bystander intervention (BI), were originally described

in 1968 within the context of social and interpersonal scenarios, however, they may also apply to medical emergencies.

The stages of BI have become the foundation for training programs focused on sexual assault and interpersonal violence prevention, cyberbullying intervention, discrimination deterrence, and health promotion.^[5,6] Virtual reality (VR) provides a unique opportunity to investigate the stages of BI in an immersive, multi-sensory environment within the emergency response field. Immersive VR places a

participant within a three-dimensional, computer-generated environment and allows programmers to control and standardize all aspects of the user's experience.^[7] In this way, the same VR scenario could be used to evaluate the actions of many different bystanders while minimizing between-user variations.

Understanding the stages of BI when confronted with a sudden medical emergency can provide valuable information about bystander latent tendencies and learned behaviors. Through a better understanding of these factors, emergency response training can be enhanced to better fit the unique conditions for each scenario, and to maximize the likelihood the person will act, when appropriate.

Sudden cardiac arrest (SCA) is the sudden and unexpected cessation of heart activity. When this happens, blood stops flowing to the brain and other vital organs. If left untreated, SCA causes irreversible brain death within minutes. An essential treatment for SCA is immediate cardiopulmonary resuscitation (CPR) and rapid use of an automated external defibrillator (AED).^[8]

Due to the low probability that any particular bystander will witness an SCA and the enormous practical challenges of observing actual SCA events, VR simulation provides an opportunity to assess the stages of BI in a controlled environment. To our knowledge, no prior research has investigated the stages of BI in an emergency while utilizing VR. Within this analysis, we hypothesized that participation in a virtual reality based simulation of a sudden cardiac arrest event would increase a participants self-efficacy and confidence to respond to an emergency.

METHODS

This project is a secondary analysis of an observational cohort study which exposed subjects to unannounced simulated SCA events in a single-player, multi-sensory, immersive, VR scenario. The SCA simulation utilized the Vive VR system (HTC Corporation, Seattle, Washington, USA) to provide a 360-degree immersive environment. Participants wore a goggled headset, audio headphones, and were able to interact with the programmed environment. This VR system allowed the participant to move in 3 dimensions within a predefined VR "play area". The VR simulation was developed as a collaboration between the investigators and a software development company working on VR and augmented reality applications. The VR simulation was tested and refined using volunteers prior the initiation of this study. Participants were recruited from the community

in and around Philadelphia, PA, USA during events held in public locations. Following consent, adult subjects completed a pre-simulation survey including demographic data, emergency preparedness, and BI questions. Subjects were told that they would encounter an emergency, but they were not informed regarding the nature of the event. Survey questions covered fire safety, first aid, the Heimlich maneuver and the chain of survival for SCA. Subjects then participated in a 3-minute VR scenario where they witnessed a simulated SCA. During the simulation, participants were placed on a virtual street with pedestrian avatars passing occasionally. The participant was given a 30-second acclimation period when they could move around and explore the virtual environment. After 30 seconds, an avatar walks by the participant and collapses in front of them. Following the collapse, additional avatars gather around the virtual victim. Virtual avatars were programmed to respond to voice commands asking for someone to "Call 911" or "Get an AED", but could only take action when directed by the study participant. The scenario concluded after 3 minutes of total simulation time, regardless of participant action or inaction, with the arrival of an ambulance and a darkening of the screen.

The scenario included audio, visual, and tactile fidelity and allowed participants to interact with programmed virtual avatars (Figure 1) via voice commands, and having the ability to perform hands-only CPR on a skills-recording manikin (Resusci Anne QCPR and SimPad, Laerdal Medical, Stavanger, Norway). The study team was also able to force avatar responses with "hot keys" in the event that the voice command was not captured by the VR system. During the scenario, participant actions, such as starting CPR and asking for an AED, were logged and time stamped. Study staff also observed the simulation and recorded participant action using a standardized checklist. Following the scenario, participants completed a post-survey, including repeat questions about emergency preparedness and BI to assess changes in comfort level. Further information about the primary study design and results are published elsewhere.^[9] Pre and post surveys were developed by the research team and piloted on volunteer participants to refine the instrument prior to any enrollments, but no validation was performed. The

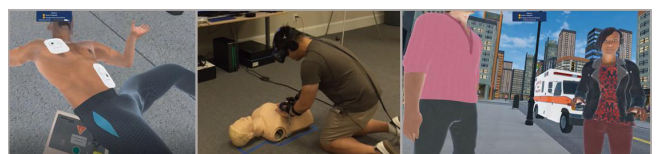


Figure 1. Virtual reality system and environment.

research protocol was reviewed and approved by the Institutional Review Board.

For this secondary analysis, participants' responses to four questions about their comfort with the stages of BI before and after the scenario were compared. The 4-point forced Likert-scale questions asked the participants to "rate how they would react if they witnessed an emergency event. I would: notice the event, interpreted it as a problem, feel responsible for dealing with it, and possess the skills to act." These questions were based on the published stages of BI and possible responses ranged from "4 – very comfortable" to "1 – very uncomfortable".^[3] Changes in response from pre-scenario to post-scenario were calculated as an integer difference with greater comfort represented by a positive value. Pre-scenario comfort, post-scenario comfort, and change in comfort were compared between demographic groups (age, gender, race/ethnicity, educational attainment, income, and employment status). Additionally, participant actions during the scenario, such as calling 911 and starting chest compressions were compared based on dichotomized comfort ("comfortable" or "very comfortable")/discomfort ("uncomfortable" or "very uncomfortable") from the pre-survey.

Analysis of categorical variables was conducted using Chi-squared tests. When appropriate, Fisher's exact was used in cases of small cell counts. To assess the odds of comfort with the stages of BI by increasing age, we used simple logistic regression. Statistical analysis was performed using R (R Core Team [2017], Vienna, Austria). Study data were collected and managed using REDCap, a secure, web-based electronic data capture tool.^[10]

RESULTS

From June 2016 to June 2017, 119 participants completed all study activities and were included in this analysis. The average age was 37±14 years, and 53 (45%) identified as female. The majority (58%, 69/119) had completed a bachelor's degree or higher. Forty-six percent (46%, 55/119) reported CPR training within the prior two years, while 18% (20/119) reported no prior training. Twenty-seven percent (27%, 32/119) had previous experience using VR equipment (Table 1). During the simulations, our research team noted that over 98% of participants noticed the event and interpreted it as a problem. Seventy-eight percent (78%) took responsibility for dealing with the event while only 54% acted appropriately demonstrating that they possessed the

necessary skills to act.

Self-reported comfort "noticing the event" increased from 80% to 96% ($P<0.001$) following the scenario and comfort "interpreting the event as a problem" increased from 86% to 97% ($P<0.001$). Similarly, comfort with "feeling responsible to act" and "possessing the necessary skills to act" also increased (56 vs. 93% and 47 vs. 63%, respectively, $P<0.001$ for both). Figure 2 illustrates the transition between each comfort level before and after the simulated event (Figure 2) for each stage of BI. Within each pane, the left axis represents pre-scenario confidence and the right represents post-scenario confidence. The ribbons connecting the left and right axes, are proportional to the number of participants who transitions from each pre-scenario category to each post-scenario category. Post-scenario, only 63% of participants felt comfortable or very comfortable that they "possessed the necessary skills to act" compared to 90% comfortable or very comfortable ratings for the other three stages of BI.

When comparing responses before and after the scenario there was no significant difference in the responses based on gender, race, educational attainment, income, or employment ($P=NS$). Furthermore, there was

Table 1. Subject demographic data

Variables	Results
Age, Mean (SD)	36 (14)
Female, n (%)	53 (45)
Race and ethnicity, n (%)	
Asian	7 (6)
Black	38 (32)
Hispanic or Latino	8 (7)
Other	5 (4)
White	60 (51)
Educational attainment, n (%)	
Some high school	1 (<1)
High school graduate or GED	9 (8)
Some college or vocational school	40 (34)
Bachelor's degree	31 (26)
Master's degree	34 (29)
Doctorate	4 (3)
Personal income, n (%)	
Under \$20,000	20 (18)
\$20,000 – 34,999	8 (7)
\$35,000 – 49,999	19 (17)
\$50,000 – 74,999	17 (15)
\$75,000 – 99,999	17 (15)
\$100,000 – 149,999	20 (18)
\$150,000 – 199,999	13 (11)
Employment status, n (%)	
Employed, working 40 or more hours per week	56 (46)
Employed, working 1–39 hours per week	40 (34)
Student	17 (14)
Not employed, looking for work	2 (2)
Disabled, not able to work	2 (2)
Retired	2 (2)
Previous CPR training, n (%)	
Never trained	20 (18)
Six to ten years ago	13 (11)
Three to five years ago	30 (25)
Current – less than 2 years ago	55 (46)

no association with age and comfort with these stages, except for post-training responsibility for dealing with the situation. In that case, younger age was associated with more comfort with taking responsibility ($OR = -0.18$ per 10-year increase in age, $P = 0.014$). Additionally, there was no difference in comfort with any stage of BI before or after the event based on the time since the last training in CPR or prior VR use.

During the simulation, a significantly larger proportion of participants who had indicated comfort taking responsibility to act before the scenario attempted to intervene during the scenario (84.6% vs. 71.2%, $P = 0.004$). No significant relationship existed in other stages of BI with pre-scenario reported comfort. Post-scenario, self-reported comfort was associated with a higher proportion of subjects attempting to intervene and possessing the skills to act (80.7% vs. 50% and 55.4% vs. 50.0%, respectively, $P < 0.001$) (Table 2).

DISCUSSION

In this study of simulated SCA using VR, we found that the majority of subjects reported an increase in comfort with all stages of BI after completing the VR scenario. Of all four stages of BI, “comfort with possessing the skills to intervene” started lowest (47%) and had the smallest magnitude of increase (+16%). When faced with the SCA in the VR environment, virtually every participant noticed the event and interpreted the event as a problem. We found no statistical difference in reported comfort with the stages of BI based on demographics, prior CPR training or prior VR use, at any time point. A significantly larger proportion of participants who had indicated comfort taking responsibility to act before the scenario attempted to intervene during the scenario.

In this study, participants were not informed of the type of emergency they would encounter nor were

Table 2. The percent of subjects who responded to the SCA event based on self-reported comfort or discomfort pre- and post-scenario

Variables	Pre-scenario		Post-scenario	
	Comfortable	Uncomfortable	Comfortable	Uncomfortable
Noticed the event	99% (92/93)	100% (23/23)	99% (113/114)	100% (5/5)
Interpreted as a problem	98% (99/101)	100% (17/17)	98% (113/115)	100% (4/4)
Took responsibility for event	85% (55/65)	71% (37/52)*	81% (88/109)#	50% (4/8)#
Possessed the skills to deal with event	53% (29/55)	56% (35/63)	55% (41/74)#	50% (22/44)#

* $P < 0.005$; # $P < 0.001$.

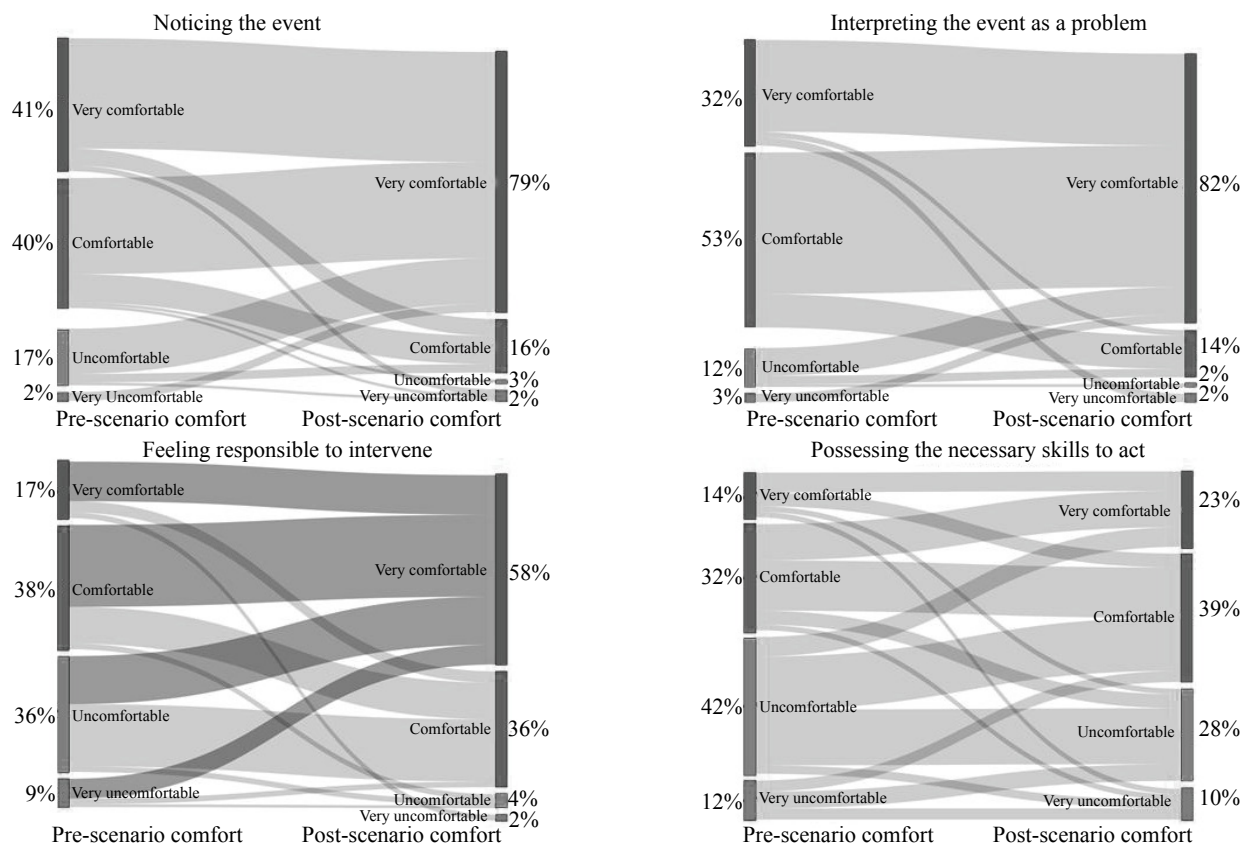


Figure 2. Sankey diagrams of the transitions between pre-scenario and post-scenario self-reported comfort for each stage of BI.

they provided with CPR skills training to complement the scenario they would encounter. It is not surprising, therefore, to see a smaller increase in reported comfort with possessing the skills to act. Utilizing a simulation and debriefing framework,^[11] and incorporating CPR skills training into the debrief could bolster a bystanders' confidence and increase the likelihood of action, in the event of a true cardiac arrest emergency.

Other studies evaluating the stages of BI have shown an ability to increase bystander action. Much of this research centers around increased BI to prevent violence and sexual assault on college campuses. Coker et al^[12] reported that an RCT implementation of the Green Dot Bystander Intervention program (designed around the stages of BI) in three Kentucky high schools resulted in a decrease in incidence of sexual violence as well as other forms of interpersonal violence. By increasing the individual's comfort with responding, they effected a change in real world actions. This approach could be effective in making a similar change in bystander response to cardiac arrest. McEvoy et al^[13] explored the role of the simulation medium (customized VR vs. non-customized VR vs. video) in the context of bullying prevention. Furthermore, Rovira and Hortensius, investigated VR in the context of bystander reaction to imminent violent events.^[14,15] These studies each investigated aspects of VR simulation study design and bystander actions. However, the current research attempted to build on these concepts and expand their use to bystander response to medical emergencies.

Research by Mausz et al^[16] showed that bystanders who provided CPR to out-of-hospital SCA victims did not feel adequately prepared to technically manage the situation and emotionally process the aftermath. The bystanders reported feeling called to act (recognizing personal responsibility to intervene) but were unsure about what actions to take (knowing how to intervene). These results are consistent with our findings that more bystanders feel comfortable taking responsibility to act than having confidence in their knowledge of how to respond. Traditional CPR training does not provide any emotional realism to the performance of skills^[17,18] while immersive VR is able to stimulate physiological, psychological and social responses from participants similar to those in the real world.^[19] By utilizing the social and physiological responses during training, VR may improve bystander confidence and better prepare them for the emotional component of response to an SCA.

In related research, VR was used to observe study

participant behavior to unanticipated and time-sensitive events. In a VR recreation of the "obedience experiment" from the 1960s, study participants exhibited the same level of physiological and behavioral response when expected to deliver an electrical shock to a "person", regardless of whether the "person" was real or virtual.^[20] Another study investigated bystander response to a request for help from victim of violent attack. This study also considered the effect of in-group vs out-of-group membership on bystander response.^[21] The concept of group membership could play a role in the results of our study, specifically the association between younger age and greater comfort accepting responsibility to deal with a situation. Since the avatars in the simulation appeared to be younger adults, participants closer to that age may have been more affected by the simulation and reported greater comfort accepting responsibility to act. Further investigation is warranted to evaluate the effect of avatar age, gender and race, particularly in relation to the simulation participant.

The higher reported comfort with taking responsibility to intervene among younger participants is interesting. It may suggest a higher degree of altruism in the younger population. However, recent research found the millennial generation (age < 39 during the study period) were no more, or less, altruistic than their GenX and Baby Boomer coworkers.^[22] Further research is needed to further investigate any age related variation in the stages of BI.

As digital technologies continue to evolve across the world, their role in new educational and training programs will continue to expand. VR represents an opportunity to immerse participants in a multi-sensory experience that could prepare professionals and bystanders alike to take action when it is needed. Conventional training modalities can convey rote skills, but lacks the stress and realism of a true medical emergency.^[17,18,23,24] VR may provide the necessary experience to convert inactive trained individuals into active bystanders who intervene. The increased feeling of responsibility reported post-scenario highlights the potential benefits of incorporating VR-based skills session into traditional CPR training content.

As a secondary analysis, this study was not powered to detect differences between demographic groups. With greater sample size, differences based on demographic or other characteristics may emerge. As with all measures of self-reported comfort, there is a risk of social desirability biasing the reported results compared to real-world application. Due to the single-player nature of the VR simulation, subjects were aware of being the only

potential intervener. This may have mitigated the dispersion of responsibility witnessed when multiple people witness the same event.^[3] Future research using a multi-player version of the simulation is needed to address this concern. Additionally, during the scenario, the avatar patient collapses and remains motionless. This does not reflect the reality of many actual SCA events in which victims exhibit agonal respirations or seizure activity.

CONCLUSION

Participation in a VR simulated SCA event was associated with increased self-reported confidence in all domains of BI. Bystanders who reported feeling more comfortable pre-simulation “taking responsibility to intervene during an emergency” were more likely to take action during a simulated emergency. VR simulation alone was not associated with as large of an increase in participant confidence regarding “possessing the skills to intervene” compared to the other 3 stages of BI. VR represents a potentially powerful tool for fostering BI for medical emergencies, such as SCA, but to be more effective, this technology should be combined with specific skill trainings to foster comfort and confidence in bystander intervention.

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final submission of this novel work which have not been previously reported.

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