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# Virtual Trainer: A Low Cost AR Simulation of a Sudden Cardiac Arrest Emergency

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**Abstract**

Sudden cardiac arrest is a leading cause of death. Because treatment must be delivered within minutes and emergency services take time to arrive, survival is strongly influenced by bystander intervention. However, bystanders are often hesitant to help. Training is a major factor in increasing the chances of bystander help. Current training uses 3D manikins which are costly and require instruction by a professional coach. We propose to make training more accessible through a low-cost approach. Our design allows trainees to practise on an interactive cloth printed with a life-sized manikin and defibrillator whilst receiving augmented reality guidance on a TV.

**Authors Keywords**

augmented reality; manuals; emergency care

**ACM Classification Keywords**

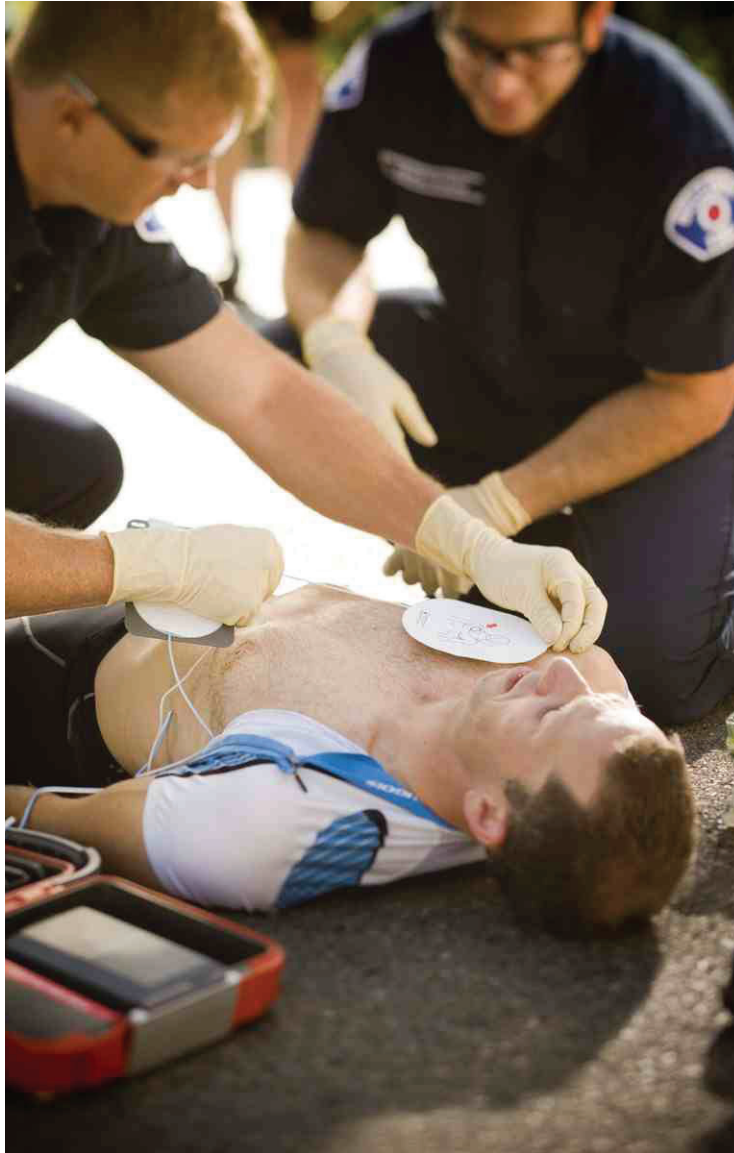
H.5.2. User Interfaces: training, help and documentation

H.5.1. Multimedia Information Systems: Artificial, augmented, and virtual realities

**Introduction**

Time matters most in sudden cardiac arrest (SCA). As a rule of thumb, the victim's chance of survival decreases with 10% for every minute without cardio-pulmonary resuscitation (CPR). Most people want to help, yet are unsure what to do. Some may even not do anything at

An emergency response team applying electrode pads to a sudden cardiac arrest victim. Because every second counts in SCA, bystanders should already start at least resuscitation and preferably defibrillation before EMS arrives.



all. Only one-third (32%) of SCA victims receive bystander CPR and only 2% are treated with automatic external defibrillators (AEDs) by bystanders (Roger et al. 2012). If bystanders provide CPR and use an AED to treat the victim before EMS arrives, survival rates increase from 10% to 38% (Weisfeldt et al., 2010).

Why are bystanders so hesitant? From usability experts in our company we hear the following. Lay responders:

- are insecure and face uncertainties that make them slow to act. They have questions such as “Can I use this on a child, a woman? Will it shock me?”
- have trouble interpreting instructions, regardless of how easy they are.
- place hands and pads in the wrong place, all the time.
- get ‘flustered’ or may even panic when confronted with the chaos and noise of an emergency scene.
- find it hard to press the shock button, even if it is the life of their partner at stake.

According to Swor et al. (2006), a bystander trained in CPR is the strongest predictor of a victim actually receiving CPR, stronger than a public location of the cardiac arrest, a bystander-witnessed event, and the bystander’s educational level. Regular training is significantly associated with willingness to provide CPR (Sipsma et al., 2011). Strikingly, SCA survival rates vary widely and are higher where CPR is part of the school curriculum or community training programs are in place. The most common way to learn resuscitation and defibrillation is with a CPR mannequin, a dummy AED and instruction by a emergency care professional. Professional CPR manikins are expensive (i.e. 250-1500 USD) as is professional coaching. Our ambition was to create a low-cost training solution for resuscitation and defibrillation which could make training more accessible.



#### **An automatic external defibrillator (AED)**

An AED case with foil-packed electrode pads in the lid, an LCD-based interface and a triangular shock button. The device in front is a resuscitation metronome which helps the first responder achieve the right speed and depth of compression. It is put on top of the victim's chest and held underneath the hands.

#### **What is resuscitation and defibrillation?**

In case of sudden cardiac arrest, the heart contracts erratically and is no longer capable of transporting oxygenated blood around the body. The basic principle behind resuscitation is simple: rhythmically pressing down on the victim's chest causes the heart to get trapped between sternum and spine and this squeezing action takes over the function of the heart. Important are the speed (110 compressions/min.) and depth (5cm) of resuscitation. Proper resuscitation is highly intensive and tiring.

Defibrillation, requiring an automatic external defibrillator (AED), involves delivering a electric shock to the patient to bring heart muscle contractions back in sync. The shock is delivered through two electrode pads which need to be stuck to the victim's body.



Despite the graphics, untrained lay responders still find it difficult to place the pads correctly on the victim's body.

### **Ideation workshop: exploring an AR-based coach**

We were interested in using augmented reality to guide trainees through an SCA emergency. Augmented reality can be seen as having two components: a computer vision component which can track objects and a display component which can show a co-located virtual overlay on top of the physical world. Both aspects are useful in virtual training. By tracking objects in the real world we can see whether users are doing the right thing and suggest corrections if needed. Through a virtual overlay we can show animated and adaptive guidance.



### **Using projection to simulate a resuscitation metronome**

Here we use projection of a Flash movie as a quick way of investigating what a resuscitation metronome could look like in AR. In particular we were interested in how to visually communicate both speed and depth through animation. The figure that is projected on is a professional resuscitation manikin.

### **Low-fi, embodied ideation**

An SCA emergency is highly physical and contextual. It involves the victim's body, the first responder's body and various tangible objects, most notably the AED and pads. Because CPR and defibrillation need to be done in a high stress situation, the trained response should ideally be almost automatic, relying more on muscle memory than cognition (Farnell, 1999; Ingold, 2001). Considering the importance of embodiment, we acted out the scene using low-fi, physical prototyping, sometimes even for the augmentation (Burns 1994; Ylirisku & Buur, 2007).



### **Using low-fi physical prototyping to explore augmentation**

This still from one of our acting out movies shows a trainee performing resuscitation on a drawn manikin in front of a TV. A mirror took the place of the TV, scouring pads with string served as electrode pads. Using a wizard of oz approach, another actor (out of view) moved the pink cardboard hands with the correct hand posture up and down to indicate the optimal speed of resuscitation.



### Acting in mirror image

Though the mirror in the ideation session helped us get started, once we tried with a mirrored camera image we found it made interaction difficult. In particular following guidance on placing the pads turned out to be highly confusing. Through experimentation with a webcam we found that the camera need not look over the shoulder of trainee as long as 'north' for the camera coincides 'north' for the trainee.



### Placing and sizing AR markers

A seemingly trivial yet tricky aspect of AR is to make sure the markers are well visible to the camera. We used a wide angle webcam to capture as wide a scene as possible. Because AR depends upon computer vision, the visibility of the markers is crucial. The size of the markers, lighting and reflectivity of the material on which the markers are printed all have a strong influence on the robustness of the augmentation and the stability of virtual objects.

### Cloth instead of paper

Whilst originally we thought of using a paper poster printed with a victim and an AED, we switched to a screen-printed textile mat. This makes the mat both easier to fold and transport and more robust. It also got rid of some of the reflection problems we had with paper.

### The conscious decision for a female victim

It is known that while males and females are equally at risk of sudden cardiac arrest (SCA), females are less likely to be resuscitated. Kramer et al. (2014) point out how CPR on females may be inhibited by socio-cultural norms about exposing female victims' chests and call for more realistic female patient simulators. This inspired us to switch from a male to a female victim and add fold-away clothing which exposes a bra.



### Training muscle memory for 'the motions that matter'

Even though VirtualTrainer could never be a high fidelity simulator because of its low cost approach, we still wanted to make trainees go through 'the motions that matter' in order to train muscle memory. We therefore added AR markers to the foldable clothing so that the system could detect whether the trainee had actually gone through the act of removing it. Similarly, we added a cloth 'lid' to the AED to train the opening action.

## Storyboarding

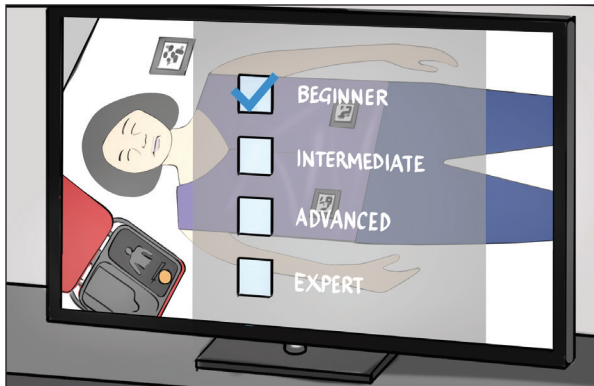
To get a grip on the full interaction flow, we made extensive use of storyboarding. The storyboard fulfilled several roles. It helped us to get feedback from stakeholders and manage their expectations before finalizing the design. It also helped us in discussions on how far we were with interaction programming, physical design, and 2D and 3D assets. Finally, it helped us communicate with photographer and videographer on how best to document the final demonstrator once it would be finished.



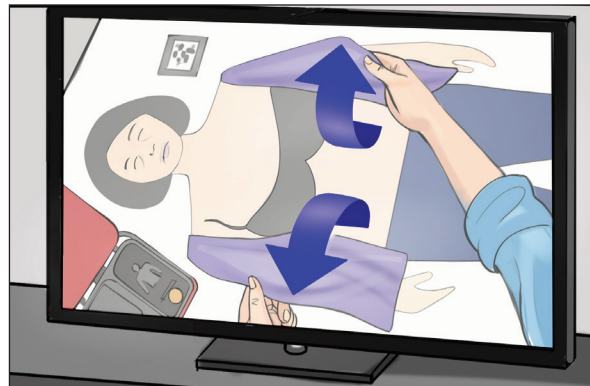
John practises SCA emergency response using the Virtual Trainer. This low-cost simulator consists of an app, a smartphone arm mount and an interactive cloth printed with a life-size victim and AED.



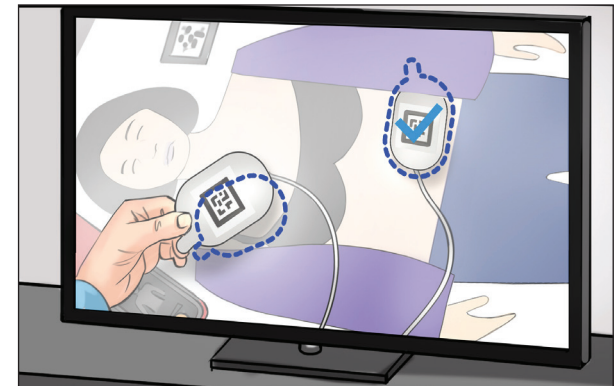
The display of the VirtualTrainer app is routed to the TV. The app augments the image captured by smartphone's camera with guidance. An arrow shows John to first open the AED.



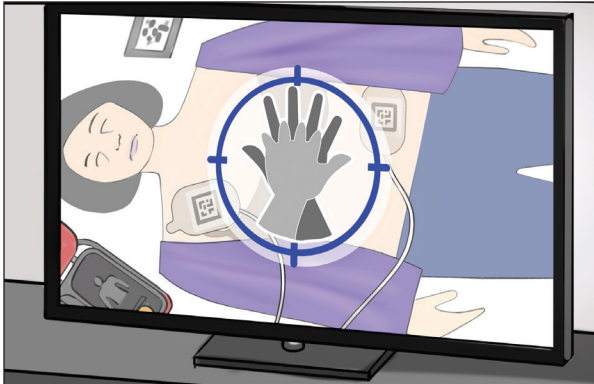
John selects the beginner checkbox. At this most basic level the system takes him by the hand and provides maximum amount of guidance and explanation. The higher the level, the less guidance the trainee receives. Regardless of level, John's actions are always monitored.



Animated arrows instruct John to remove the clothing, a crucial step that is sometimes overlooked. The shirt can be opened so that John actually needs to go through the physical actions. This also confronts John with the embarrassment hurdle he may feel when the victim is a female stranger.



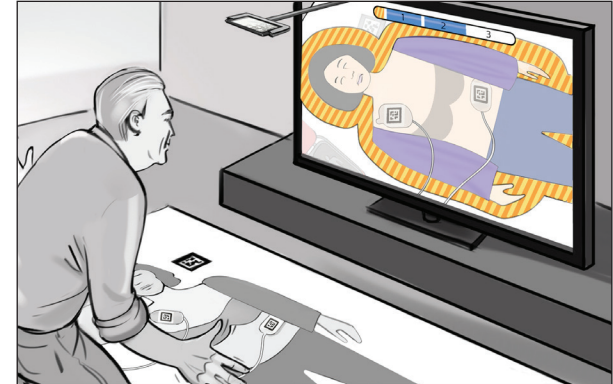
The system comes with a pair of tangible practice pads. By means of dotted outlines John is shown where to put these pads on the body. The system monitors the position and orientation of the pads to check whether John accurately places the pads and places a checkmark once they are placed correctly.



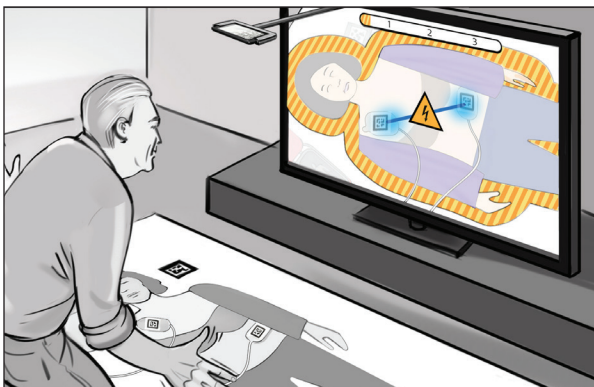
Using an animation, the Virtual Trainer shows John how to adopt the interlocking hands grip, the most effective hand posture for chest compressions.



An auditory beat and visual feedforward indicate 110 compressions/min. with optimal depth and release. A timer shows how much longer he needs to continue. Trying to keep pace, John realises how physically demanding resuscitation is.



The system has decided to deliver a shock. It indicates that John should stay clear from the body and shows a count down bar.



When the countdown has finished, a shock is visualized.



At the end of the session, John is shown a report summarizing his performance. This includes the time taken, the number of errors, the correctness of the pad placement and the effectiveness of his resuscitation.





#### **Webcam instead of smartphone**

For our demonstrator, we chose to use a webcam connected to a laptop instead of an AR app on a smartphone. This allowed for faster development with less time-consuming compilation as well as a more robust set-up since the laptop could be connected straight to the TV. Modern TVs could in fact work directly with a webcam as they have the necessary computational power on-board. For actual product development, compilation for iOS or Android should pose no problems.



#### **The low cost package**

Virtual Trainer comes as an interactive cloth and a webcam which are to be used in combination with a TV.

## Final demonstrator



The interactive cloth is laid down in front of a TV. It is printed with a life-sized mannequin and a defibrillator (AED). A camera is attached to the TV and tracks the trainee's actions, allowing augmented reality guidance to be shown on the TV.



Though the mannequin and AED are flat, they have tangible qualities where it matters, allowing the trainee to practise the most important actions. Here the trainee needs to go through the motions of opening the lid of the AED.



AR guidance shows the user what to do and a coach tells him what to do. Here dotted outlines indicate where to put the pads which are tracked by the camera. Once they are in the right place this is confirmed through tick marks on the pads.



Inside the mat there is a pressure sensor. An animated metronome provides guidance on the required speed and pressure during resuscitation. When speed or pressure are off the coach gives additional instructions by voice (e.g. "Press harder").



At the end of the session, the user is shown analytics, e.g. if any mistakes were made and how much time the user spent on time-critical actions.

We shot a three minute contextual video explaining the purpose and use of VirtualTrainer. This allowed us to circulate the concept more widely than by means of the demonstrator alone. We gathered feedback from various people within the company including business stakeholders, usability experts and designers from our emergency care unit.



## Discussion

We share some of the feedback we received and add our own reflections.

### *1. AR offers both guidance and monitoring*

Though AR is typically associated with virtual overlays, we found that the computer vision functionality of AR can be very useful by itself to monitor the user's actions. This is most obvious in VirtualTrainer's expert mode in which users receive no AR guidance but do benefit from an analysis of their actions.

### *2. Acting out is a natural ideation companion for AR*

In AR, embodiment can play a very strong role as it opens up possibilities for rich user actions and spatial, situated feedback. We found that that acting out with physical props was a powerful way of exploring embodied AR scenarios. This is particularly the case for co-location, the notion that virtual objects can be accurately placed within the user's real-world environment.

### *3. There are two loci of attention: mat and TV*

Trainees need to split their attention between their actions on the cloth and the guidance shown on the TV. Suggestions to overcome this were to use projection or head-mounted displays. Both add cost and complexity and do not gel with our vision of a low-cost solution. For now, our recommendation is to put the TV as low as possible to minimize ergonomic discomfort, i.e. neck strain.

### *4. Training could have value for diverse target groups*

In addition to community training or training at schools, VirtualTrainer could be provided to individuals who buy an AED for peace of mind at home. This would offer family of people at an increased risk of cardiac arrest the possibility to be better prepared. Another target group could be policemen and firemen who do not have the same level of medical training as an EMS team yet are often among the first on the ground at an emergency scene.

### *5. Virtual Trainer as part of our emergency care offering*

Virtual Trainer could be offered as part of an end-to-end emergency care offering to help improve the effectiveness of our AEDs. It could also form the basis of a product-service combination which offers training and certification for users. Virtual Trainer could also have a PR role, showing to the outside world that our company sells more than 'just the product' and works on training solutions to optimize the life-saving capabilities of our AEDs.

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