EMuRgency: Addressing cardiac arrest with socio-technical innovation in a smart learning region

Marco Kalz[1], Joris Klerx[2], Gonzalo Parra[2], Jesko Elsner[3], Max Haberstroh[3], Stefaan Ternier[1], Daniel Schilberg[3], Sabina Jeschke[3], Erik Duval[2], Marcus Specht[1]

[1]Centre for Learning Sciences and Technologies, Open University of the Netherlands
[2]HCI Lab, KU Leuven
[3]Institute of Information Management in Mechanical Engineering, RWTH Aachen
marco.kalz@ou.nl, joris.klerkx@cs.kuleuven.be,
gonzalo.parra@cs.kuleuven.be, Jesko.Elsner@ima-zlw-ifu.rwth-
aachen.de, Max.Haberstroh@ima-zlw-ifu.rwth-aachen.de,
stefaan.ternier@ou.nl, daniel.schillberg@ima-zlw-ifu.rwth-
aachen.de, sabina.jeschke@ima-zlw-ifu.rwth-aachen,
erik.duval@cs.kuleuven.be, marcus.specht@ou.nl

Abstract. This paper introduces the EMuRgency project. The project has the goal to increase awareness and competences regarding the problem of cardiac arrest in the Euregio Meuse-Rhine (EMR) and to use socio-technical innovations to transfer it into a smart learning region. Based on the conscious competence framework solutions for stakeholders on different levels of the framework are introduced, namely a public display network, mobile learning apps and a volunteer notification system. Finally, a future research outlook is given.

Keywords: resuscitation, CPR, smart learning region, AED, awareness, conscious competence, mobile apps, volunteer notification

1   Introduction

Sudden Cardiac arrest is a medical condition in which the heart suddenly and unexpectedly stops beating. In Europe, it is estimated that approx. 350 000 people die from cardiac arrest each year [1]. Traditional interventions have neither sufficiently decreased mortality rates nor increased the rate of cardiopulmonary resuscitation (CPR) especially by first responders. In the Euregio Meuse-Rhine (EMR), the rate of bystander resuscitation is approx. at 27% [2]. In other countries and regions there is a rate between 65% and 75% of bystander resuscitation before the professional emergency medical services (EMS) arrive on

scene. The project "EMuRgency-New approaches for Resuscitation Support and Training" is a socio-technical innovation project with the target to increase the rate of bystander resuscitation and on the long run increase survival chances and the quality of life in our region. In this paper we describe the overall concept, activities and the technical architecture of the project and discuss the connection between the technical artifacts, stakeholders and the educational opportunities.

2   Problem description

The problem of cardiac arrest has a long history in science and technology. According to Cooper et al. [3] the first initiatives for training of experts have been started around 1930 while the formal training of laymen has been even sanctioned in 1974. Nowadays, after years of research and monitoring of survival rates, resuscitation councils worldwide and the International Liaison Committee on Resuscitation (ILCOR) have constantly updated the guidelines for CPR, making it difficult for laymen and even professionals to stay aware of the latest guidelines and requirements for resuscitation. While for a long time there was a focus on educating only experts and to provide the highest standards possible (including artificial respiration (mouth-to-mouth) in exchange with cardiac massage) the update of the guidelines in 2010 [1] has opened the way for the so called "hands-only" CPR for laymen. Hands-only CPR by bystanders has been shown to deliver sufficient quality to improve survival rates compared to conventional CPR [4]. A meta-analysis has found that an increase of survival rates of approx. 22% can be reached when dispatcher-assisted hands-only CPR has been delivered to victims of a cardiac arrest [5].

In general, research has acknowledged that for a time-critical incident like a cardiac arrest in combination with arrival times of professional emergency services in Europe between 8 – 10 minutes, the efficient training of laymen is important to increase survival rates [6, 7]. Recently mobile devices have been used to offer training or performance support for CPR. Kovic & Lulic discuss the role of mobile devices in the so-called "chain of survival" [8]. In another study it has been confirmed that the use of a notification system for bystanders is an effective method to lead potential first responders to the victim and therefore decrease the untreated time-interval before cardiac massage is conducted [9].

From an educational perspective, the required knowledge and competences to perform efficient CPR are not very complex; nevertheless, in order to persist them and to have a sufficient level of self-efficacy to perform it in an emergency scenario, it is still an issue for research and development. While projects in the domain of technology-enhanced learning often focus on the development of solutions for complex problems for a small number of experts in the project we are facing the opposite problem: How to increase awareness, knowledge and self-efficacy for a problem that requires only a small set of competences and knowledge from a large number of people? For this purpose the activities of the project are organized along the so called "conscious competence matrix" as depicted in fig. 1.
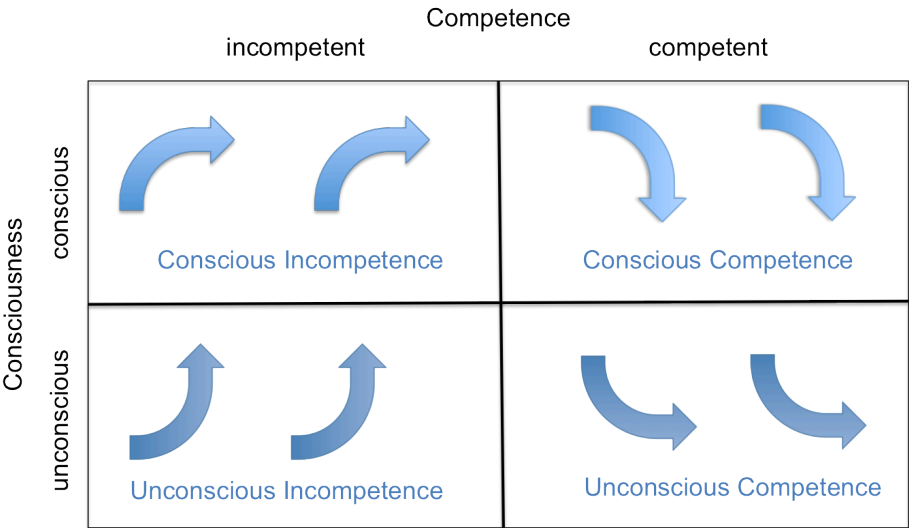

Fig. 1. The Conscious Competence Model

This competence model assumes that all learning processes start from a state of unconscious incompetence. In this state the learner is not aware about his incompetence and the skill area or problem. The aim of any intervention on this level is to move a learner from this stage to the stage of conscious incompetence. On this stage a learner becomes aware of the existence and importance of a skill and ideally makes a commitment to improve these skills. The next stage is the conscious competence stage. This stage is reached when a skill can be performed reliably at will. On this stage the learner can perform the skill

without assistance but it is not already an automated skill. Practice and repetition is required in order to move to the last stage of the model. The highest stage of the model is achieved when a skill becomes automated.

In the EMuRgency project we are focusing on the first three levels of the competence model. Technological and educational innovations are developed to reach people on these levels. Table 1 shows the competence models, activities and stakeholder groups of the project. These levels are not exclusive, but the project is aiming to lead people from the general public through these levels.

Competence Level	Activity	Stakeholders
Unconscious competence	Public Display Network, Activity Streams, 30s video	The general public
Conscious incompetence	Mobile apps, E-Learning Content, Training in schools	The general public, school children & parents
Conscious competence	Volunteer Notification System (VNS)	"Educated" volunteers

Table 1. Competence levels, activities and stakeholders of the EMuRgency project

In the next chapter we describe the technical infrastructure developed in the project. We start with the display network and the activity stream prototype, discuss educational innovations and introduce the Volunteer Notification System (VNS).

3   Technical Infrastructure of the EMuRgency project

3.1   Display Network

Public ambient displays are increasingly used in our surroundings i.e. train stations, universities, shopping malls etc. [10]. These kinds of displays have a potential to become a global and powerful communication channel. Ambient displays are well suited as a means to keep users aware of people or general states of large systems, like network traffic and weather, or in the case of this project, health. For example, we can

use a display to make people aware of the survival chances in their own region in case of a cardiac arrest. Knowing about these survival chances, they might decide it would be good to learn about resuscitation in case an incident happens in their own environment. Furthermore, we aim to use these public displays as they offer the needed affordances that can help to:

- increase procedural knowledge of laymen about resuscitation, like: the basic steps (i.e recognize, check for breathing, call for help, and start chest compressions), places where to learn these steps, etc.
- strengthen factual knowledge on the subject; how many cardiac arrest are happening in a specific region, what are the corresponding survival rates and how many volunteers are registered in my neighborhood, etc.
- recruit new volunteers for the EMuRgency notification system in order to create a safer region.

We will now first introduce the technology that the project has put in place for creating a network of public displays. Secondly, we will introduce the first prototype applications that have been developed for the display network.

An infrastructure for managing public displays has been deployed with the use of Signage-technology [11]. This infrastructure allows us to set-up a network of displays across the region in a variety of places such as train stations, waiting rooms, hospitals, etc. on a multitude of devices from big screens (i.e. projectors, televisions, etc.) to smaller and more personalized screens such as tablets, smartphones, etc. Figure 3 presents the EMuRgency network of public displays.
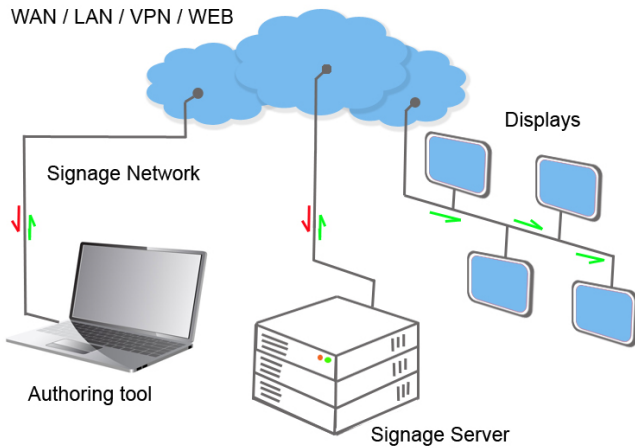
Fig. 2. The EMuRgency network of public displays

The Signage network has a dedicated server connected to the Internet. The authoring tool called *Signage Studio* can be installed on any computer to administer stations connected to the Signage server. This tool allows us to design different so-called 'campaigns' with different types of contents such as videos, pictures, webpages, etc. The designer of the campaign can assign, update or schedule different campaigns to individual or multiple stations, as long as they are connected to the signage server. Each of these stations is connected to the network by running a signage player. Interested display owners can join the signage network through the installation of a dedicated client, the use of a unique URL or the integration of media from the project into their own system.

As described previously, the aim is to increase laymen's emotional involvement. The public displays therefore show awareness-raising videos, facts about cardiac arrest, and near-live data visualizations. The method and guidelines used to design and develop our display campaigns are listed by Schmidt & Terrenghi [12] .These include:

- Embedding information where and when it is useful. For example, when a person is sitting in a waiting room of the hospital, he or she might be more accessible then usual for information about cardiac arrest.

- The information provided should not be forced onto people or their immediate environment. It should invite them to reflect on the information and potentially decide to learn about resuscitation and become a volunteer within the system.
- Aesthetics are of key importance and it should be reflected in the design. A rapid prototype design methodology from paper mockups to digital prototypes, which can be evaluated with real users in real-time settings, is therefore adopted.

Three types of content have been developed until now. First of all, a video has been produced in three languages (Dutch, German and French) to increase procedural knowledge about resuscitation. This video can be accessed online at the YouTube channel of the project[1]

Secondly, a web application has been created based on so-called "Social Awareness Streams" or "Activity Streams (AS)" to enable volunteers to share thoughts, activities and information with different types of contacts [13]. These streams can be either stand-alone (such as Twitter), or be embedded into other system (such as the Facebook news feed). This web application allows us to capture different events and provide the possibility to embed these on the different software components developed in the project, as seen in Figure 3.

For example, when a training course is scheduled and shared through the EMuRgency Activity Stream (AS) the details will be automatically disseminated to (i) the mobile VNS client that is running in the devices of the users, to (ii) the public displays of the Signage network, and (iii) in the project's news feed. Currently we are storing and distributing different types of activities, such as: case events, training-courses, upcoming events, AED locations, texts and video resources. The VNS Server is connected to the EMuRgency AS in order to share and store the different case events reported across the region. On a later stage, these will be post-processed and different visualizations are created using the aggregated data.
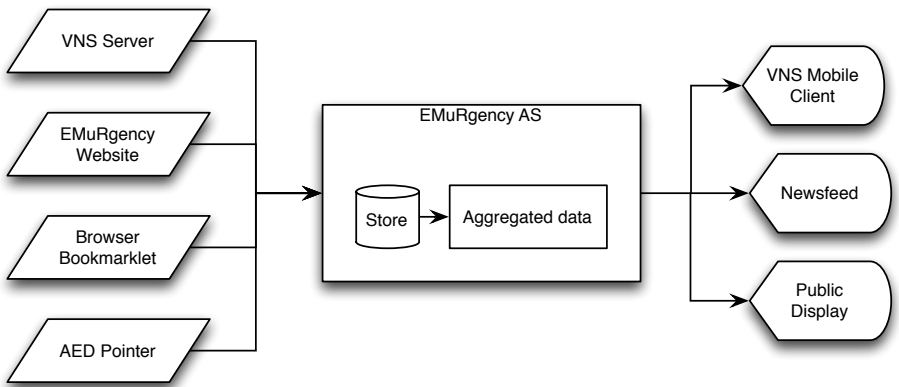
---

[1] http://bit.ly/emUrgency

Fig. 3. The EMuRgency Activity Stream architecture.

The third type of content is a heatmap visualization of the Euregio Meuse-Rhine. A geographical map is drawn on the display, covering the whole region where the project is active. A heatmap is overlayed where the range of - from blue to red - colors encodes the number of medical incidents to which an ambulance was called. Blue indicated little incidents while red means many incidents. Extra controls have been added to filter on specific time-periods. Together with a 'play' button, a user can see the number of incidents over time. At this time of development, the data for this visualization comes from the P2000 monitor in the Netherlands (http://www.p2000-online.net/). This monitor is part of the communication network of the Dutch emergency services such as the police, ambulance and firemen. Hence, the heatmap is only shown above the northern part of the geographical map. Once the VNS is used by the dispatcher systems in the three countries, we will have data of all parts of the EMR region and therefore the heatmap will cover the complete map. Furthermore, the data from P2000 is not cardiac-arrest specific, which means that the heatmaps shows all incidents to which an ambulance was called. Our aim is to visualize the number of volunteers in the regions in a similar way.

As method for active contribution of data/crowdsourcing, the AED-Pointer platform will be used to locate metadata about locations and access to Automated External Defibrillators (AED) in the region. These data are not publicly available and can thus not be used by the professional services or the VNS.

3.2 Educational innovations for CPR training

In the project we have followed a proposal by Handley [14] to structure the training activities according to three different levels: The bronze level is the minimal training unit a layperson does need to take appropriate action (check, call, compress), the silver level includes artificial respiration and finally the gold level is compliant with the curriculum of basic life support standard (BLS). On all levels an optional AED module can be done. This curriculum is the basis for several educational innovations targeted at learners from level 2 and 3 of the conscious competence model.

To increase the flexible access to CPR training, we have first started to develop a standard E-Learning solution that can be used by the general public or by institutions from the region that would like to offer CPR training to their employees. This E-Learning unit will be published as an Open Educational Resource in two formats: A stand-alone version that can be used for individuals and a version in SCORM-format that can be used in Learning Management Systems of the institutions.

A second approach to increase the access to low-threshold CPR training is the use of video-units and mobile training apps. For the use in the display network, but also for preparatory activities of face-2-face training sessions we have developed a 30-second video about cardiac arrest and the basic steps. Other authors have reported positive effects of instructional videos and reminder videos about CPR [15]. Especially the study presented in [16] has demonstrated the effectiveness of video-based CPR training for laymen/first responders. We are currently conducting a study aiming to show that even with shorter videos basic knowledge building processes are initiated. For the development of a mobile training app we are currently finalizing a review of existing CPR apps. Existing apps have been first evaluated by domain experts with regard to their correctness, functionalities and compliance with current guidelines. In addition we have conducted a usability evaluation of the best 13 apps with laymen. These findings will inform the design of our own mobile learning app for CPR training.

For traditional group training approaches we are currently evaluating a game-based learning concept that has the goal to make CPR training more authentic compared to the classical 4 hour training that is divided into lecture and training on a manikin. Instead we have used the AR-Learn framework [17] to design a training concept in which couples of

players explore content items with a mobile phone, followed by addressing a case scenario in their direct environment in which CPR is needed. Player A uses the mobile phone to access content items and for routing to a case in their direct vicinity the other player uses the phone to record the performance. These recordings are later compared to a gold-standard video and the players have to do a self-assessment of their performance. Their self-assessment is then discussed with an instructor who is responsible to provide feedback to the players.

3.3   The Volunteer Notification System (VNS)

The Volunteer Notification System (VNS) is a prototype solution for offering faster response treatment by involving volunteers into the chain of survival. The basic concept of the VNS is the location tracking of the registered users and putting it in context to the location of an ongoing emergency situation. In case of an incoming emergency call, the VNS uses this information in order to notify those potential helpers who are geographically close to the place of incident and therefore can arrive on scene before the professional EMS (Emergency Medial Services).

Current progress in mobile technologies and the continuous growing popularity for portable digital devices with Internet access (e.g. Smartphones, Tablet PCs etc.) offer a great potential for the development of new solutions like the VNS. By simply using existing hardware and infrastructure and without supplying any special devices, a VNS is able to reach many potential volunteers. Some of the notable built-in features modern mobile devices own are real time internet connections, notification options with several possible ways to get the volunteers attention (e.g. sound, vibration etc.) and a great variety of context sensors to enable situation-based functionality like GPS, compass, tilt, etc. In addition, almost all modern mobile devices run operating systems (OS) that can be accessed with open Advanced Programming Interfaces (APIs) so that third-party developers can write their own applications for those devices.

Even for the core functionality of the VNS – i.e. the effective localization of volunteers - different companies and research groups are working on solutions, offering a variety of frameworks with base functionality to access localization data for different types of devices. One of the most advanced examples is Android's Location API, which is part of the Android software platform, developed by Google in conjunction with the Open Handset Alliance (OHA).

Whenever the VNS receives information on a new emergency it will identify potential volunteers in the close vicinity of the incident and immediately inform those in walking distance of the ongoing emergency.

The distance, that an individual can travel within a given time interval, depends on many different parameters. Walking speed, for example, differs from person to person, depending on age, fitness, etc. but also on group compositions (e.g. walking with children). Another parameter is the topology of the incidents, location, or the type of movement by which a volunteer travels to the incident (e.g. by car, bicycle or walking). In order to meet these concerns, a personalized profile setting is created, giving any registered volunteer the option to define an individual notification distance by configuring the appropriate parameter in their user profile. To maintain a realistic range, the maximum distance a user can set is limited to 1 km at the moment.

As long as a client is not involved in an ongoing case, the main communication that occurs between the mobile clients and the server is a client-to-server location publishing that automatically gets invoked in a predefined time interval. While a simple implementation approach for this is a common HTTP POST method, the push communication used to send data from the server to a specific client is an entirely different matter. The World Wide Web (WWW) was originally not intended to support bidirectional communication and therefore does not include the corresponding specifications or protocols. With HTML 5 introducing the WebSocket JavaScript interface, a native solution for bidirectional communication is available. Once a WebSocket connection has been established between client and server, instant data communication becomes possible between both sides without explicitly having to deal with technical differences. Based on this kind of real time connectivity, a variety of different features can be implemented, including chat channels for notified helpers and live camera streaming from the place of incident. With HTTP requests generally including a response-content, the message flow for general information and event data has been implemented as a HTTP response to an occurred location update and thus does not need any special connectivity but internet access.

Analyzing the base functionalities, there is one type of message that cannot wait for the next "location publish" in order to be sent as a reply from server to client, but instead needs to be send instantly; a new case notification message. This message initiates a new case on the server and alarms any potential helper in walking distance to the emergency;

the message needs to arrive on the client with the smallest delay possible.

In order to push messages from a server to a mobile client, different cloud messaging solutions are available but generally represent very individual solutions that only work for specific devices or operation systems. Our messaging architecture at this point of development, uses common HTTP posts that are implemented for client-to-server location updates; the response content of the HTTP posts is processed in order to send event data from the server back to the client; new cases are initialized by using device specific APIs in order to push notification messages from the server to the mobile clients; and a real time Web.

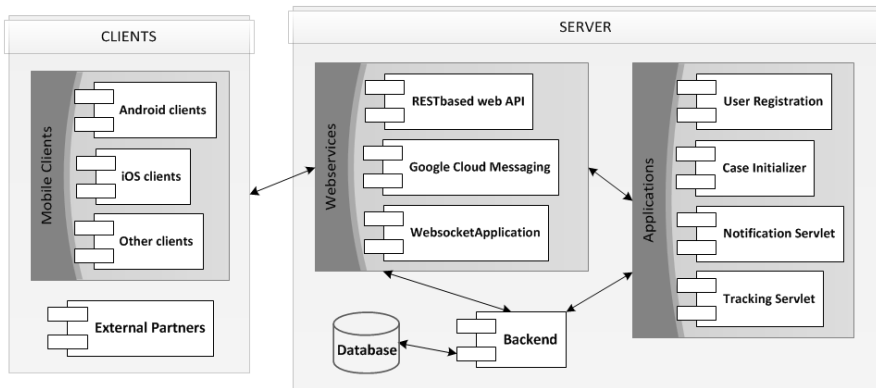The architecture of the EMuRgency VNS is illustrated in Fig. 4.

Fig. 4. Essential components of the EMuRgency VNS

Currently, several test and evaluation scenarios with partners are set up in the region and possible collaboration scenarios are being discussed with the local dispatch centers in order to integrate the VNS within the existing emergency workflow.

4   Discussion and Outlook

The EMuRgency project contributes to the idea of "smart cities learning" by addressing a global problem with regional and local approaches. Cardiac arrest is an exemplary problem that can neither be solved by medical, technical or educational solutions alone. Hence, the project is a socio-technical innovation project that uses a combination of technologies and interventions to make citizens in the Euregio Rhine-Meuse aware of the problem (step from unconscious incompe-

tence to conscious incompetence) and offer them low-threshold educational solutions that increase their knowledge, competences and self-efficacy in case of a cardiac arrest (step from conscious incompetence to conscious competence). Thus one of the underlying models we propose for smart cities learning scenarios is flow process that starts from awareness raising to non-fomal learning activities and formal learning activities and ends up in volunteering to help to address societal problems as depicted in fig. 5.
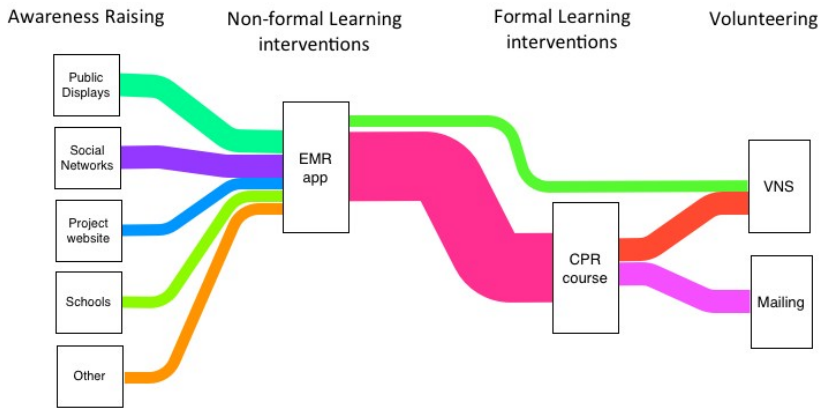

Fig. 5. EMuRgency educational flow process

The infrastructure in the region is used to support this awareness-raising and involvement of the general public. During the first 12 month of development, the necessity of a seamless integration between the technical- and the sociological components became obvious. With the system depending on volunteer participation, the public awareness on both, the general topic of Sudden Cardiac Arrest and also the public opinion on the project itself, is of crucial importance. Promising concepts rely on long term planning of citizen involvement; starting at school age and confronting children and teenagers with the importance of realizing and detecting medical emergencies and offering continuous possibilities for all citizens of all ages to learn and participate in offered courses and training possibilities. It is important to underline, that a long-term citizen involvement cannot be achieved by a one-time implementation of a simple pre-defined concept, but instead requires the collaboration and engagement of people from different interest groups; e.g. institutional, organizational and private.

Acknowledgement

References

1. Lippert, F., Raffay, V., Geogiou, M., Steen, P., Bossaert, L.: European Resuscitation Council Guidelines for Resuscitation 2010 Section 10. The ethics of resuscitation and end-of-life decisions. Resuscitation. 81, 1445–1451 (2010).
2. Fries, M., Beckers, S., Bickenbach, J.: Incidence of cross-border emergency care and outcomes of cardiopulmonary resuscitation in a unique European region. Resuscitation. 72, 66–73 (2007).
3. Cooper, J., Cooper, J., Cooper, J.: Cardiopulmonary Resuscitation History, Current Practice, and Future Direction. Circulation. 2839–2849 (2006).
4. Bobrow, B. J., Spaite, D. W., Berg, R. A., Stolz, U., Sanders, A. B., Kern, K. B., ... & Ewy, G. A.: Chest compression–only CPR by lay rescuers and survival from out-of-hospital cardiac arrest. JAMA: The Journal of the American Medical Association, 304(13), 1447-1454 (2010).
5. Hüpfl, M., Selig, H. F., & Nagele, P. (2010). Chest-compression-only versus standard cardiopulmonary resuscitation: a meta-analysis. The Lancet, 376(9752), 1552-1557.
6. Nishiyama, C., Iwami, T., Kawamura, T., Ando, M., Yonemoto, N., Hiraide, A., & Nonogi, H.: Effectiveness of simplified chest compression-only CPR training for the general public: a randomized controlled trial. Resuscitation, 79(1), 90-96 (2008).
7. Abella, B. S., Aufderheide, T. P., Eigel, B., Hickey, R. W., Longstreth Jr, W. T., Nadkarni, V., ... & Hazinski, M. F.: Reducing barriers for implementation of bystander-initiated cardiopulmonary resuscitation. Circulation, 117(5), 704-709 (2008).
8. Kovic, I., & Lulic, I.: Mobile phone in the chain of survival. Resuscitation, 82(6), 776-779 (2011).
9. Ringh, M., Fredman, D., Nordberg, P., Stark, T., & Hollenberg, J.: Mobile phone technology identifies and recruits trained citizens to perform CPR on out-of-hospital cardiac arrest victims prior to ambulance arrival. Resuscitation, 82(12), 1514-1518 (2011).
10. Wisneski, C., Ishii, H., Dahley, A., Gorbet, M., Brave, S., Ullmer, B., & Yarin, P.: Ambient displays: Turning architectural space into an interface between people and digital information. In Cooperative buildings: Integrating information, organization, and architecture. Springer Berlin Heidelberg, 22-32 (1998).
11. Want, R., & Schilit, B. N.: Interactive Digital Signage. Computer, 45(5), 21-24 (2012).
12. Schmidt, A., & Terrenghi, L.: Methods and guidelines for the design and development of domestic ubiquitous computing applications. In Proceedings of the 2006 ACM symposium on Applied computing (SAC '06). ACM, New York, NY, USA, 1928-1929 (2006).
13. Naaman, M., Boase, J., and Lai, C.: Is it really about me? Message content in social awareness streams. In Proc. CSCW '10. ACM, 189-192 (2010).

14. Handley, A. J.: Compression-only CPR? To teach or not to teach?. Resuscitation, 80(7), 752-754 (2009).
15. Ahn, J. Y., Cho, G. C., Shon, Y. D., Park, S. M., & Kang, K. H.: Effect of a reminder video using a mobile phone on the retention of CPR and AED skills in lay responders. Resuscitation. 82(12). 1543-1547 (2011).
16. Bobrow, B. J., Vadeboncoeur, T. F., Spaite, D. W., Potts, J., Denninghoff, K., Chikani, V., ... & Abella, B. S.: The Effectiveness of Ultrabrief and Brief Educational Videos for Training Lay Responders in Hands-Only Cardiopulmonary Resuscitation Implications for the Future of Citizen Cardiopulmonary Resuscitation Training. Circulation: Cardiovascular Quality and Outcomes, 4(2), 220-226 (2011).
17. Ternier, S., Klemke, R., Kalz, M., Van Ulzen, P., & Specht, M.: ARLearn: Augmented reality meets augmented virtuality. Journal of Universal Computer Science, 18(15), 2143-2164 (2012).