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Virtual Reality in First Aid Education: Increasing Knowledge and Confidence for CPR Performance

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Abstract:

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Virtual Reality in First Aid Education: Increasing Knowledge and Confidence for CPR Performance

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First aid plays a critical role in emergency situations, as correct procedures significantly increases the chances of survival and recovery. However, bystanders are often hindered by a lack of knowledge, confidence, and overall self-efficacy when it comes to performing first aid. To address this, there is a need for effective educational tools that can boost both knowledge and confidence in performing first aid. This study aims to design, develop, and evaluate a Serious Game (SG) delivered through a Virtual Reality (VR) experience, utilising situated learning to teach cardiopulmonary resuscitation (CPR) on an unconscious person. The study begins by presenting existing challenges, statistics, and initiatives related to first aid awareness, followed by a review of related work in VR, SGs, and situated learning. The VR experience was then developed and tested with a before-and-after test, using a pre- and post-questionnaire to measure changes in participants' knowledge and confidence. The results show a significant increase in both knowledge ($t = 5.49$, $p = 0.000$ ($\alpha < 0.05$)) and confidence ($t = 6.377$, $p = 0.000$ ($\alpha < 0.05$)) among the participants ($N = 20$), supporting the potential of VR as an effective tool for teaching CPR and enhancing bystander confidence in emergency situations.

Index Terms: Medialogy—Master Thesis—First Aid—Virtual Reality

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1 Introduction

According to the definition by Merriam-Webster [32], *first aid* refers to the immediate care provided to a person experiencing a sudden injury or illness, with the goal of preventing the condition from worsening until professional medical assistance is available. Intervening in such emergency situations not only promotes recovery but, in extreme cases, can also be critical in preserving a person's life.

According to the World Health Organization (WHO) [48, 49], unintentional injuries such as road traffic crashes, falls, drowning, burns, poisoning, etc. are among the top causes of death each year, highlighting the need for first aid. Equipping people with basic first aid knowledge and skills enables them to effectively contribute to emergencies, which can potentially save lives, prevent severe injuries, and stabilise a person's condition until help arrives. Additionally, preparing people can promote confidence and recognition of emergency situations, allowing them to act swiftly when times matter the most [42]. It is also important the note, that equipping the proper knowledge and procedures about first aid is crucial, as incorrect first aid can cause further injury or worsen the condition [7].

According to the 2023 year report from Dansk Hjertestopregister [12], approximately 5000 danes experience cardiac arrest when out of the hospital (OHCA patients) annually. The survival rate of these OHCA patients has increased throughout the years, thanks to multiple initiatives that has sought to bring forth knowledge, increase public awareness, and encourage bystander intervention when it comes to performing first aid [15].

For instance, the Hjerteløber initiative launched in 2017 by TrygFonden [15,46] encourages bystanders to become voluntary 'runners'

for Automated External Defibrillators (AEDs). The volunteers download a mobile application and receive alerts if the emergency services are notified of a nearby OHCA case, allowing them to locate and bring a nearby AED to the scene.

Another public initiative is the Restart a Heart Day campaign, established by the European Resuscitation Council in 2012. It is an annual recurring international awareness day about cardiopulmonary resuscitation (CPR) and its importance. Restart a Heart Day encourages individuals, schools, organizations, communities, etc., to participate in CPR training by hosting events, participating in training, spreading awareness themselves, sharing content or stories online, and much more [6].

Additionally, as of 2005, it became a legal requirement to integrate first aid education into the Danish public school syllabus, in an attempt to increase population-wide knowledge [38]. However, according to a 2024 nationwide survey done in correspondence with a report by Syddansk Universitet [28], only a third of 6-9th graders have received life saving first aid education. In the survey, they have recorded that only 2 out of 10 class teachers assess themselves as competent enough to teach first aid to their students, and that external education, such as professional first aid courses, is evaluated by the school board to be a significant expense.

Today, Danish healthcare organizations such as Røde Kors and Falck offer first-aid courses and online resources relevant for both adults and children [17, 39]. Additionally, they offer courses that are held on the school grounds and offer relevant material to educate teachers and students of all ages, in a familiar and convenient environment. Besides regular first aid courses, first aid is also taught through various channels, such as in the context of getting a driver's license, workplace training requirements, or out of personal interest. These educational opportunities aim to equip individuals with the essential skills of first aid, but the effectiveness can vary depending on factors such as teaching methods, accessibility, or personal feelings.

A key barrier in emergency situations is the lack of confidence in one's ability to perform first aid. Although, many people receive basic first aid training, multiple studies and surveys [8,14,30] indicate that the bystanders' willingness and confidence to perform first aid correlates with their perceived competence.

Even among individuals who have previously been trained in first aid, they still fail to perform CPR on OHCA patients [14, 28, 30]. There are various reasons as to why people who may be capable, but not willing to perform CPR. Some of the common reasons are: fear of causing further harm to the injured person, lack of confidence or training, uncertainty of recognizing a proper cardiac arrest, and experiencing the Bystander Effect - a phenomenon where people are less likely to intervene in the presence of others [3, 14, 22, 26].

In a study from 2018 on attitudes towards bystander CPR in Scotland, Dobbie et al. [14] found that nearly half of the respondents ($N = 1027$) did not feel confident in administering CPR. Among the top causes of barriers were the fear of worsening the injury, visible signs of blood/vomit, lack of skills, lack of confidence, or concern that the person was a drug user. Among the respondants without prior training, the most common reason for not performing CPR was a lack of skills.

Because of this, multiple initiatives have been made to improve these skills and confidence, such as the ones mentioned previously, but also in the form of digital training and education.

1.1 Serious Games

Over the past decades, the use of *Serious Games (SGs)* has emerged as a rapidly expanding tool for teaching a variety of skills. SGs enable users to be taught, trained, or informed through game-based or simulated environments, creating a balance of education and entertainment. This approach facilitates interactive and immersive learning, where the user is able to apply their skills and experiences in a controlled environment or a game-based scenario [5, 11, 51]. SGs have been used in a wide range of fields, such as physics, nature, politics, engineering, and has seen a significant rise in the medical field [47, 51]. When used in a classroom setting, it has also shown to increase motivation, engagement, and increase various skills for children [1, 35, 44].

For instance, Khowaja [24] developed an SG to teach and improve vocabulary skills for children with autism. The results show that the children did in fact improve upon the learning of the selected vocabulary items and were able to retain them over a longer period of time.

Using SGs has also shown an increase in objective awareness [19] and learning motivation [36], making them an excellent tool to be used for medical education.

In the context of first aid education, Boada et al. [9] created a 2D mini-game SG aimed at teaching high school students how to respond to choking incidents. The results show increased levels of both enjoyment and knowledge, suggesting that using SGs is a good strategy for first aid training.

Similarly, Latif et al. [25] designed and developed an SG to teach regular people about CPR by placing them in a simulated scenario of an industrial worker who needs to help to their colleague experiencing a heart attack. The results from their evaluation also demonstrates that using an SG was an effective tool to teach about CPR.

1.2 Learning through Virtual Reality

In addition to SGs, *Virtual Reality (VR)* has also emerged as a transformative tool in recent years, with significant applications in both entertainment and education [23, 40]. By immersing users in simulated 3D environments through a head-mounted display (HMD) and controllers, it offers unique opportunities and interactions for experiential learning.

These simulated environments provide a safe, controlled space where users can apply their skills and knowledge without the risks associated with real-life situations. This makes VR particularly valuable for training scenarios, allowing learners to practice and refine their abilities in a risk-free setting [20].

When used in combination with SGs, it enables the creation of realistic and immersive learning environments that allow users to

practice their skills and apply knowledge in a controlled environment, without being limited by intractability or real-life constraints. They also allow recreating situations or environments that are too difficult, expensive, or unsafe in real life [4, 37].

For instance, a study by Nassar et al. [34] explored VR as a tool for surgical education. From their findings, they found that VR simulations can be used in high-risk situations, such as surgery, to facilitate technical and non-technical skills. They advocate for VR, as it allows for risk-free repetitions, learning through trial and error, and being able to provide appropriate feedback to the user.

In addition to this, Merchant et al. [31] conducted a meta-analysis to evaluate the effectiveness of VR-based instruction on learning outcomes in K-12 and higher education students. Their review, which included studies on games, simulations, and virtual worlds across various topics, found that VR-based applications improve learning outcomes. Their analysis also revealed that simulations providing elaborate explanations as feedback were more suitable for declarative tasks (focused on understanding concepts), and that using correct-response feedback is more suitable for procedural tasks (focused on gaining new skills).

In the context of first aid, Artero et al. [2] conducted a comparative study evaluating CPR training through VR versus traditional classroom instructions. The results shows that the participants in the VR testing group performed higher-quality chest compressions than the compared control group, suggesting that virtual simulation can used in enhancing CPR performance. However, the study also noted some limitations; that they did not assess the participants' prior first aid knowledge or skills, before conducting the test, and that they did not include any theoretical evaluation to measure potential knowledge gains.

A systematic review and meta-analysis from Zhao et al. [50] compared the examination pass rates between medical students who were educated using VR and those who were educated through traditional methods. The findings show that students who received VR-based education had a significantly higher pass rate than those taught through traditional methods. This indicates that VR may enhance learning and should be adopted into medical training programs. However, the authors acknowledged certain limitations, including that they had a small sample size of studies, in a small geographical coverage, which could introduce bias. They emphasized that VR should serve as a supplement to traditional education rather than a replacement, as it may not be suitable for all clinical contexts, such as in highly sensitive areas, like as surgery.

A study from Rainer et al. [37] sought to develop a VR SG, aiming to enhance first aid education and assess the viability of using VR controllers compared to hand-tracking. Their game was designed to teach essential first aid procedures, including basic first aid, first aid for choking, and first aid for bleeding, across three different levels/environments. Evaluating their game using a usability test, they concluded that using VR controllers offer a significant increase in usability than hand-tracking.

Another study from Nas et. al. [33] aimed to assess the long-term impact of CPR training through face-to-face or VR on participants' willingness to perform CPR, retain CPR knowledge, and disseminate CPR awareness. The results indicate that as little as a 20-minute session of CPR-training either through face-to-face or VR has shown a significant increase in the willingness to perform CPR on strangers and good retention of CPR knowledge. However, they do acknowledge several limitations; their follow-up only assessed theoretical knowledge and not participants' actual CPR performance skills, making it unclear if the participants' are able to perform the correct procedures during actual emergencies. The authors also did not include a pre-test survey before the start of their study to assess the participants' current skills or knowledge, making it difficult to compare the outcome metrics.

Situated Learning

In relation to educating people through immersive environments, *Situated Learning*, a term coined by Jean Lave and Etienne Wenger [27], refers to the learning theory emphasising that learning is best understood and most effective when it is embedded within an activity. Additionally, Dawley and Dede [13] expresses that *"situated learning occurs when a student experiences and applies learning in a specific environment or setting that has its own social, physical, and cultural contexts"*.

Situated learning can be effectively facilitated through VR, as it is a powerful tool for creating immersive environments that can mimic real life. Using VR for situated learning has emerged as an ideal approach for teaching and training. Multiple studies [10, 21, 29] have documented successful applications of VR and situated learning.

Specifically, a study from Huang and Liaw [21] integrated situated learning for medical students in a VR environment of a hospital. They offered a system that provided the students with options to explore 3D representations of human organs and allowed them to engage with medical scenarios, equipment, and patients. The results from their study shows a significant improvement in the students' motivation to learn, and understanding of anatomical models, suggesting that immersive learning tools can be a valuable supplement to traditional teaching methods.

In the context of first aid, Bucher et al. [10] iteratively developed and evaluated a VR application aimed at teaching first aid skills and increasing knowledge of CPR. In their second iteration of the simulation, they assessed knowledge gain, accessibility, and usability through a mixed-methods study. The results show a significant increase in knowledge about correct procedures when it comes to emergency situations, supporting VR as a viable alternative training method for situated learning. However, the authors do acknowledge some limitations of their study, such as their small sample size of participants, no long-term knowledge retention assessment.

This study aims to design, develop, and evaluate a virtual reality serious game focused on situated learning to enhance knowledge and confidence in basic first aid, particularly CPR. Developing this application will help identify challenges and opportunities for future projects, reinforcing the potential of virtual teaching methods in first aid education.

This leads to the research question for this study:

"How can a Virtual Reality experience be used to increase knowledge and confidence in performing cardiopulmonary resuscitation (CPR)?"

2 Methods

This study was a working collaboration with the Danish healthcare and emergency reponse company, Falck, as they are one of the top providers of healthcare services. Their involvement provided the opportunity to consult first aid experts, and course leaders, as well as other healthcare professionals. This collaboration aided in ensuring the accuracy of the first aid content and ethical standards. Additionally, it assisted in ensuring that the training material was conveyed correctly to avoid accidentally exposing the participants to unsafe or misleading information.

2.1 VR Experience

The VR experience was developed using the Unity Game Engine (v. 6000.0.40f), utilizing Unity's XR Interaction Toolkit (v. 3.0.7) for VR development. The VR headset used for development was the Meta Quest 3S and its corresponding controllers.

Since this study focuses on teaching CPR, it was natural to develop a VR environment placing the player in relevant first aid scenarios. However, given the vast range of situations requiring first aid (e.g., car crashes, heart attacks, falls), the scope was narrowed to a single scenario for the purposes of this study. In this scenario, the player is alone in the environment and must perform CPR on an unconscious person independently, rather than interacting with multiple people. This approach focuses on teaching the player how to act confidently and effectively when they are faced with an emergency situation alone.

By creating this VR environment, situated learning is emphasized, as it allows the player to take their time and learn correct procedures through repeated interaction and practice.

The game flow for this scenario, consisting of specific tasks, was developed in collaboration with Falck and aligned with standard CPR and first aid procedures. This game flow includes only a snippet of the general CPR procedure encountered in real life, excluding steps such as the unconsciousness person regaining consciousness, placing the person in the recovery position, or using an AED. Limiting it to the most basic tasks will make the information easier for the participants to digest, and set the scope for the development (see Figure 1).

At the start of the VR experience, the player is placed in a small tutorial area designed to teach them how to interact with the virtual environment using the VR controllers. This "practice" area is intended for users who may be less familiar with VR, ensuring they understand the controls before entering the main scenario. It includes instructions on how to use the controllers to interact correctly with game objects and other elements (see Figure 2).

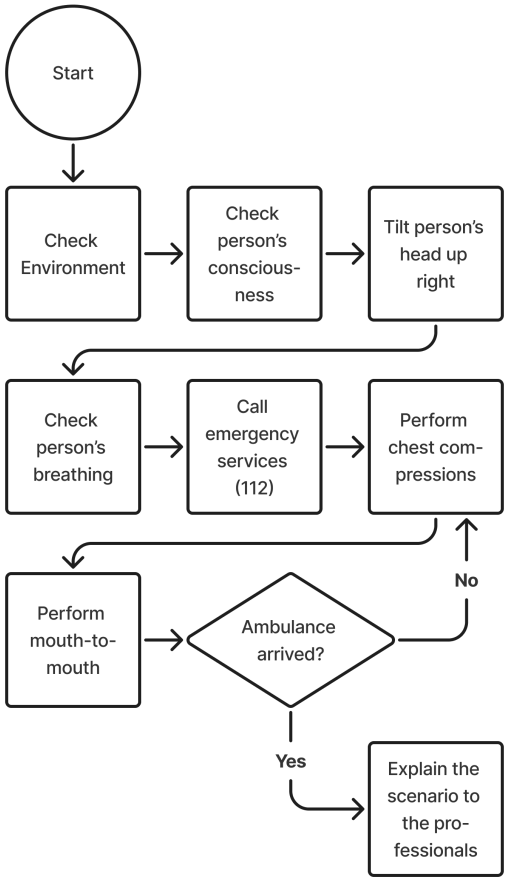

Figure 1: Flowchart of the scenario.

Figure 2: Overview of the tutorial area.

Check Environment

After completing the tutorial, the player is placed into the main scenario's virtual environment, which depicts a quiet suburban area with no other people around. This relatively isolated setting reinforces

the idea that the player is alone, making the solo nature of the first aid scenario more believable. The player's initial position is at the side of the road, where they spot the 'unconscious person' who has crashed into a nearby tree on their bike in front of them (see Figure 3).

Throughout the whole VR experience, the player is guided by user interface (UI) elements (see Figure 4) that provide context to the scenario and instructions on how to proceed. These include explanatory text and images sourced from Falck's official first aid handbook [16]. The UI updates dynamically based on the current situation and the actions the player needs to take. At the beginning of the VR experience, the player is introduced to the scenario through a brief explanation displayed via the UI.

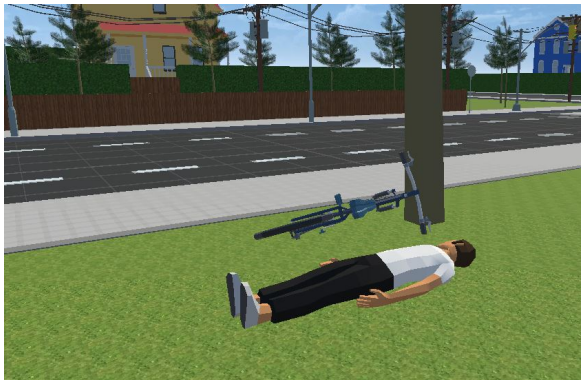

Figure 3: Overview of the scene with the unconscious person lying beside their bike next to the road, with buildings in the background.

Figure 4: Example screenshot of the UI explaining to the player how they should perform mouth-to-mouth.

As shown in the flowchart (see Figure 1), the player is asked to begin checking the environment for any dangers surrounding the unconscious person and look for potential bystanders who might be able to assist them. This step ensures that the scene is safe and that the player avoids putting themselves in harm's way. As previously mentioned, the unconscious person is already in a safe location, and the player is alone. After 15 seconds of scanning the area, the player is prompted via the UI to approach the person to check their condition.

Check Consciousness

When the player arrives next to the unconscious person, they are 'teleported' beside them using the XR Toolkit's *teleportation event*. Additionally, their movement controls get disabled in order to lock them in place, as to not have them accidentally move around. Here they are prompted to the next step: checking the person's consciousness.

They do this by physically crouching down and interacting with both of the *interactable game objects, "interactables"*, attached to the person's torso and stomach (see Figure 5). The VR experience is designed to be stationary, meaning the player does not need to physically move around to navigate the VR environment, except for kneeling down. When the person is interacted with, an animation plays that 'rocks' them back and forth to show the player they are interacting correctly. After 5 seconds of interaction, it goes to the next step: to tilt the person's head upright and tilt their jaw upwards.

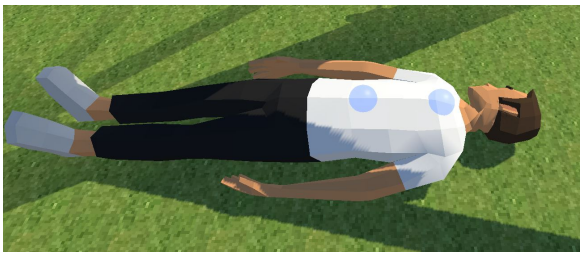

Figure 5: Point of view screenshot of the interactables attached to the torso and stomach. They are indicated with a translucent light blue sphere.

These "interactables" serve as the player's primary points of interaction throughout the experience. They are attached to various parts of the unconscious person's body and update according to the corresponding interaction state. Their colour remains consistent across the entire experience to ensure visual continuity. When the player interacts with an interactable correctly, it visually disappears, providing clear feedback. Additionally, *haptic feedback* is triggered in the corresponding controller, and the player's hand pose is automatically adjusted to demonstrate the correct hand positioning for each step.

By providing feedback on the player's actions, the system reinforces that their input is recognised, aligning with findings from previous research on effective learning through interactivity.

Check Breathing

After tilting the person's head upright, the player must check if the person is breathing normally. Activating the corresponding interactables opens the person's mouth, and the player's hand models adopts the appropriate real-life pose (see Figure 6). To simulate a breath check, the player must physically lean in and bring their ear close to the person's mouth. There is no sound or visible indication of breathing, as in this scenario, the person is non-breathing. When the Head-Mounted Display (HMD) is detected within the designated "listening zone" for at least 2 seconds, it advances to the next step: calling emergency services.

Figure 6: Point of view screenshot of the mouth interaction. The top image shows the interactables attached to the person's jaw and nose before being interacted with. The bottom image shows the hands posing as you interact with the interactables.

Call Emergency Services

The phone is instantiated in the player's virtual "pocket", allowing them to pick it up and use it. The player interacts with the phone by grabbing it and pressing the *trigger button* on the same controller used to hold it. Pressing the trigger once initiates a call to emergency services, and pressing it again activates the phone's speaker. Visually, the phone screen updates to reflect these interactions, accompanied by a 'beep' and 'ringing' sound for additional feedback. Once the call is in progress, the player is prompted to place the phone on a highlighted area on the ground beside them and move on to the next step: check compressions (see Figure 7).

Figure 7: Point of view screenshot of the phone game object attached to the player's hand as they are calling emergency services. The area for putting the phone down is highlighted by the same translucent light blue color as the interactables.

Chest Compressions

After placing the phone down, the player is immediately prompted to begin chest compressions. The UI and active interactable guide the player to place their hands in the middle of the chest, instruct how fast to compress, and indicate that they need to press down firmly 30 times. The UI includes a counter displaying the number of compressions completed, helping the player keep track. Additionally, a 'pulsing circle' accompanied by a metronome-like sound signals the tempo, set at 110 BPM (beats per minute), which falls within the recommended range of 100–120 BPM [16]. For easier readability, a smaller "mini" UI is displayed just above the unconscious person next to the interactable, which also show the current compression count and tempo. When the player interacts with the interactable using both hands simultaneously, their fingers visually interlace to demonstrate the correct hand positioning for effective compressions and allows them to make the actual compressions (see Figure 8). After the player has successfully done 30 compressions, it moves to the next step: mouth-to-mouth.

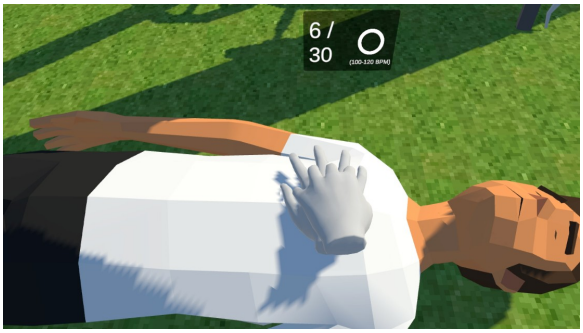

Figure 8: Point of view screenshot of the player performing chest compressions. Their hands are posed as they are actively interacting with the interactable. The "mini" UI is shown at the top, displaying that they have currently performed 6 out of the 30 compressions. The 'pulsing circle' is next to it, showing the tempo.

Mouth-To-Mouth

After completing the chest compressions, the player is prompted to perform mouth-to-mouth breathing. Similar to the breath-check state, the player must open the person's mouth by interacting with the corresponding interactables and physically bring their head close to the person's mouth. When the player's head remains near the mouth for 5 seconds, it counts as the two deep breaths (see Figure 6).

After completing the mouth-to-mouth breathing, the interaction switches back to chest compressions. The player cycles between chest compressions and mouth-to-mouth breaths until the ambulance arrives. Once the player finishes the mouth-to-mouth breathing for the first time, the ambulance is queued to arrive at the player's destination. After 30 seconds, the ambulance can be heard approaching from a distance with its siren, simulating its arrival.

Ambulance Arrival

When the ambulance arrives, all interactables are disabled as the healthcare professionals take over. The UI instructs the player to explain what has happened, what actions they have performed so far, and any observations about the unconscious person (see Figure 9). After this, the screen fades to black, signaling the end of the VR experience.

Figure 9: Point of view screenshot of the ambulance.

2.2 Evaluation

The main purpose of this study was to determine whether the developed VR experience has the potential to effectively teach CPR procedures and increase users' confidence in performing first aid. By evaluating the VR experience through testing, it is possible to determine its potential by receiving critical feedback and suggestions for future improvements. Similar to the approach used by Bucher et al. [10], the evaluation used a before-and-after design, testing the same participants both before and after the VR experience. This method enables an assessment of the VR application's potential impact. The evaluation focused on measuring changes in participants' knowledge and confidence, and consisted of three parts: a pre-questionnaire, the VR experience itself, and a post-questionnaire.

Participants

The evaluation consisted of a single test that was conducted throughout a week at Aalborg University (AAU) in Copenhagen. The test participants were gathered through convenience sampling, whom were fellow university students. The test was conducted on a total of 20 participants ($N = 20$) across different studies and semesters. Of the participants, 12 identified as male, 7 as female, and 1 as other. 17 of the participants were in the age group between 23-25, with the remaining 3 being between 26-31.

19 out of the 20 participant had previously attended first aid courses. Of those 19, 10 (50%) of them attended a course in relation to obtaining their driver's license, 4 (20%) attended through school/education, and 5 (25%) in relation to work or similar. However, 15 (75%) of them have not attended a first aid course within the last three years, while 2 (10%) had attended a course within 12 months, and 2 (10%) within 1-3 years.

19 out of the 20 participants had previous experience with VR. Of those 19, 13 (65%) of them used it often in relation to school, work, or in their free time, 4 (20%) of them had a little bit of prior experience, 2 (10%) of them had tried one or twice, and 1 (5%) had never tried it before.

Instrumentation

The first of the three parts, the pre-questionnaire, was completed on a laptop (see Figure 10). This questionnaire collected demographic information such as age and gender, as well as participants' prior experience with first aid courses and VR. It then assessed their current first aid knowledge, focusing on the topics covered in the VR experience. The knowledge questions were developed based on official competence criteria from Dansk Førstehjælpsråd (DFR) set for professional first aid courses, as well as information from general Danish sources offering free first aid guidance, including Sundhed.dk [41], TrygFonden [45], and Falck [18]. These knowledge questions are a mixture of multiple choice, sequence-order, and true/false statements.

Following the knowledge questions, the test participants were also asked to rate their current confidence in performing first aid using a 7-point Likert scale. These confidence questions were based on previous research related to first aid confidence, ensuring the participants' perceived ability to respond effectively in emergency situations.

The full list of questions and their responses can be seen in Appendix A.

After the test participant had read through the consent form and completed the knowledge and confidence questions, they were guided to the center of a blanket and fitted with the Meta Quest 3S headset and its corresponding controllers (see Figure 10). Before beginning the VR experience, participants were informed that they could ask questions at any time if they felt confused and were allowed to opt out if they experienced any symptoms of 'cybersickness' (such as nausea, dizziness, or headaches).

They were also encouraged to "think aloud" during the session to provide insights into usability. Additionally, participants were reminded that they would be physically observed by the test conductor, and their gameplay would be recorded via the Meta Horizon mobile application. This live casting/recording enabled made it possible to monitor the participant's actions and assist them if they became stuck or encountered any bugs. Both physical and virtual observations were noted and collected as part of the data.

When the ambulance arrived in the VR experience and the screen faded to black, the participant's session ended. They were then asked to remove the VR headset and return to the laptop to complete the post-questionnaire. This questionnaire included the same knowledge and confidence questions from the pre-questionnaire (see Appendix A) to evaluate any changes or improvements in the participants' responses following the VR experience. Additionally, participants were asked to provide feedback on positive and negative aspects of the experience, along with any suggestions for improvements or additional features. Finally, a quick debriefing session was conducted with the test conductor, giving participants the opportunity to share verbal feedback and ask any further questions about the experience.

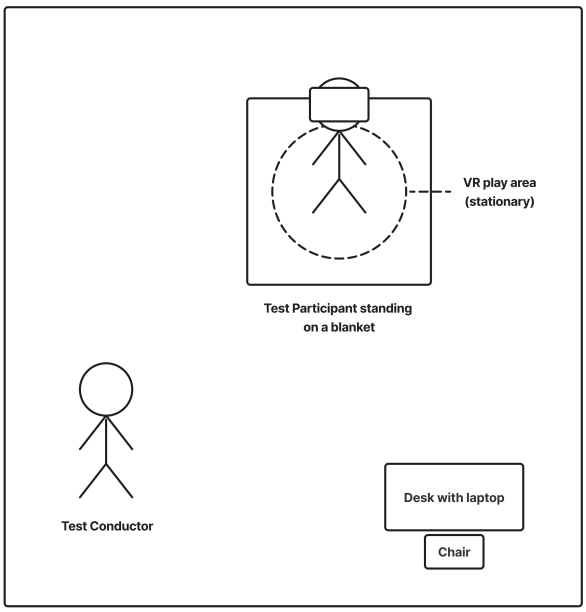

Figure 10: Sketch of the test setup layout. The test participant is standing on a blanket in order to make it more comfortable for them when they have to kneel down to interact with the unconscious person in VR. The test conductor stands away from the participant and the laptop in order not to interfere.

3 RESULTS

To determine any differences or improvements in the participants' knowledge and confidence regarding performing CPR, data were collected and analysed. A general overview of score changes was obtained by calculating the mean of the pre- and post-test scores. Additionally, the Shapiro-Wilk test was used to assess the normality of the data distribution for each test. To evaluate the statistical significance of the observed changes, paired t-tests were conducted, and well as Cohen's d. The detailed interpretation of these results will be presented in the Discussion section (Section 4).

The full list of answers can be seen in Appendix A.

3.1 Knowledge Test

For the knowledge test, each of the participants' answers was converted into points: 1 point for a correct answer and 0 for a wrong answer.

The total points each participant could get is 11 points, with the eight knowledge questions (whereas the sequence question can give up to 4 points). Calculating the mean of the answers from the pre-questionnaire shows a total score of 7.8 ($\sigma = 2.215$) across all participants. The post-questionnaire has a mean score of 10.45 ($\sigma = 0.826$), making an increase of 3.65 points (34% increase) (see Table 1).

A Shapiro-Wilk test was performed to determine if the data are normally distributed. The results confirm that the data are normally distributed with $W = 0.926$ and $p = 0.131$ ($\alpha < 0.05$).

Because of the normal distribution, a paired t-test was calculated to determine the significance of the increase. The results show a significant increase in knowledge gains with $t = 5.49$ and $p = 0.000$ ($\alpha < 0.05$).

Additionally, Cohen's d was also calculated to determine the effect size. The results indicates a very large effect size with $d = 1.228$.

The observed increase in knowledge and confidence aligns with the high rate of correct task performance demonstrated by participants during the experience. As seen during the observations and participants' think-alouds, when they were stuck or confused, they took extra time to reread the UI instructions to better understand the required actions. Once they understood the task, participants were able to perform it with little to no difficulty and reinforced their learning through repetition, such as when doing chest compressions and mouth-to-mouth breathing.

Participant Number	Pre-Test	Post-Test	Diff.
Participant 1	4	11	7
Participant 2	5	11	6
Participant 3	11	11	0
Participant 4	9	11	2
Participant 5	8	10	2
Participant 6	6	9	3
Participant 7	5	8	3
Participant 8	11	11	0
Participant 9	10	10	0
Participant 10	7	11	4
Participant 11	9	10	1
Participant 12	5	10	5
Participant 13	10	11	1
Participant 14	8	11	3
Participant 15	8	10	2
Participant 16	10	11	1
Participant 17	10	10	0
Participant 18	8	11	3
Participant 19	7	11	4
Participant 20	5	11	6
Mean Score	**7.8**	**10.45**	**2.65**

Table 1: Table of mean knowledge scores for each individual participant before and after the test, including the difference.

3.2 Confidence Test

The confidence test consisted of five questions, each answered using a 7-point Likert scale ranging from 1 ("Fully Disagree") to 7 ("Fully Agree"). The participants' responses were converted into numerical scores for calculation purposes. An important note, one of the five questions was negatively worded: "I would be worried about doing something wrong when I am trying to help in an emergency situation". To accurately calculate the overall confidence increase, this item's scores were reversed by subtracting the original response from 8 (as the scale ranges from 1 to 7).

Calculating the mean score shows an increase from 4.24 ($\sigma = 5.105$) for the pre-test, and a score of 5.23 ($\sigma = 4.043$) for the post-test, making an overall positive difference of 0.99 (23.3% increase) (see Table 2).

Once again, a Shapiro-Wilk test was performed to determine if the data is normally distributed. The results confirm that the data is normally distributed with $W = 0.956$ and $p = 0.475$ ($\alpha < 0.05$).

To determine the significance of this increase, another paired t-test was calculated. The results show a significant increase in gained confidence with $t = 6.377$ and $p = 0.000$ ($\alpha < 0.05$).

Cohen's d was also used for the confidence test to determine the effect size. The results indicate a similar large effect size with $d = 1.426$.

Examining individual participants' scores reveals clear differences in how the test impacted their confidence levels. For example, Participant 12 had a slight decrease in confidence in their post-test responses. Specifically, two questions showed a negative shift: "I feel I am able to help a stranger in an emergency situation" and "I feel able to be calm in an emergency situation." For both, their responses changed from "Indifferent" to "Slightly Disagree."

Participant Number	Pre-Test	Post-Test	Diff.
Participant 1	4.2	4.4	0.2
Participant 2	3.8	5	1.2
Participant 3	5.2	5.6	0.4
Participant 4	4.2	5.4	1.2
Participant 5	6	6.4	0.4
Participant 6	3.6	5.6	2
Participant 7	2.4	3.8	1.4
Participant 8	5.4	6	0.6
Participant 9	4.8	6.4	1.6
Participant 10	5.4	6	0.6
Participant 11	2.8	4	1.2
Participant 12	4.4	4.2	-0.2
Participant 13	4.8	5.8	1
Participant 14	2.8	5.6	2.8
Participant 15	4.4	5.4	1
Participant 16	4.2	5.2	1
Participant 17	4.8	5	0.2
Participant 18	3	4	1
Participant 19	5.4	6	0.6
Participant 20	3.2	4.8	1.6
Mean Score	**4.24**	**5.23**	**0.99**

Table 2: Table of mean confidence scores for each individual participant before and after the test, including the difference.

From the observations, many participants encountered difficulties at some point during the experience, not due to the first aid instructions themselves, but rather from usability challenges. Initially, many participants struggled with using the phone to call emergency services until they received verbal guidance.

Qualitative feedback gathered during the VR experience and post-test debrief showed that participants generally had a positive impression. They particularly highlighted that the experience was easy to use, the information was clear and understandable, and the interaction feedback was effective.

4 Discussion

The test results showed a significant increase in participants' knowledge and confidence regarding CPR after using the VR experience. This suggests that the VR application could serve as a suitable method to improve CPR knowledge and confidence, consistent with findings from previous research.

However, it is important to examine the results, observations, and participant feedback more closely to understand whether other factors influenced their responses.

Revisiting the confidence test results (Table 2), Participant 12 showed a slight negative shift in their confidence score. This could be due to several reasons: they may have forgotten their initial answers, experienced the Dunning–Kruger effect [43] (initially overestimating their abilities and later adjusting their self-assessment after the presented challenge), or other factors entirely. From their qualitative feedback, Participant 12 mentioned uncertainty about how long to perform certain actions, which might explain the drop in confidence.

Additionally, during the pre-questionnaire, some participants expressed feeling "stupid" or that they "knew the answer but forgot it." Specifically, Participants 12 and 18 expressed these feelings, yet both showed significant knowledge gains. This uncertainty may have motivated them to focus more intently on the VR experience, as to gain more knowledge about the topic.

It is also important to note that the confidence test relied solely on self-reported data. Unlike the knowledge test with objectively correct answers, self-report measures are purely based on participants' subjective feelings and interpretations of the questions, which may introduce bias through exaggeration or understatement.

From the observations, many participants struggled to use the *trigger-button* on the controller to interact with the phone, despite it being explained during the tutorial. Participants often attempted to use their opposite hand/controller to press the buttons on the phone, as it seemed more intuitive for them. Most of the participants eventually learned to interact with the phone through trial and error, though some required a little verbal guidance from the test conductor. Additionally, a few participants encountered technical issues such as janky interactions, unintended rotation while seated, and slow response during mouth-to-mouth interaction, which may have affected their confidence or caused confusion.

Regarding the UI, participants demonstrated two interaction styles: some read the instructions before starting to interact with the interactables, while others ignored the UI and focused solely on the interactables. When the latter did not receive any feedback from the interactions, they would then check the UI. This suggests the need to accommodate different approaches, ensuring critical information is accessible even for those who "race" through the experience.

It should be noted that the VR scenario took approximately 5 minutes on average to complete. The ambulance arrives after just 30 seconds after completing the initial interaction cycle, which is unrealistically fast compared to real-life emergency response times. While this may create a misleading impression about ambulance arrival times, it was a necessary design choice to prevent participants from being forced into a long-duration test. One participant mentioned in the post-test debrief that this timing felt appropriate, as it allowed them to cycle through chest compressions and mouth-to-mouth breathing multiple times without dragging out the experience.

As a part of the test, the participants were also asked to pro-

vide positive-, and negative feedback, and suggestions for the VR experience. Most participants praised the clear instructions and explanations, describing the VR experience as a useful refresher that boosted their confidence. They found the system simple, intuitive, yet realistic enough to convey the urgency of helping someone in need. Additionally, they mentioned that the UI and audio cues were effective indicators for compression tempo and correct actions, aligning with the observed improvements in test scores.

Nevertheless, some negative feedback was also reported. Participants noted occasional stuttering, bugs, and a bit of jankiness during some interactions with the unconscious person and the phone. A few participants felt there was missing or unclear feedback, such as not knowing the exact proximity required during the mouth-to-mouth interaction or how long and forcefully to blow into the mouth. A few participants experienced mild cybersickness related to the *locomotion-movement* used, expressing a preference for *teleportation-movement* as an alternative. Others found reading the UI inconvenient because it was positioned above and away from the unconscious person, forcing unnatural head movements during interactions. This suggests that the placement of the UI is critical in order for them to read it. These issues likely contributed to some frustrations and may have impacted overall results.

Most of the participants suggested several usability improvements, including adding more visual and auditory feedback, increasing controller/interactable leniency, and incorporating a step where healthcare professionals step out of the ambulance, where they have to explain the situation to reinforce the correct response. One participant recommended using the VR headset's built-in microphone to better simulate mouth-to-mouth breathing or simply adding breathing sounds to guide blow force and duration.

This study did not include practical skill assessments, only theoretical knowledge and confidence measurements. Therefore, it remains uncertain whether participants could perform these first aid actions effectively in a real emergency situation.

Since participants were tested only once immediately after the VR session, it is unclear whether knowledge and confidence gains are retained over time. Future studies assessing long-term retention would provide valuable insight in this regard.

Future development could enhance the VR experience by adding more scenarios and expanding upon the common CPR procedures, such as handling the unconscious person regaining consciousness, placing the person in the recovery position, including NPCs (non-player characters) that assists the player, and integrating the use of an AED.

Overall, this study supports the use of VR for situated learning in teaching CPR, consistent with prior research. However, the relatively small sample size of participants ($N = 20$) suggests that further development and testing are needed to clarify the extent of knowledge and confidence gains.

5 Conclusion

This study aimed to design, develop, and evaluate a VR experience for teaching first aid, specifically to increase knowledge and confidence in performing CPR. Developed in collaboration with the Danish healthcare company Falck and grounded in prior research, the VR application was built using standard VR development practices with a focus on situated learning.

The evaluation demonstrated that VR can effectively enhance both knowledge and confidence related to CPR, aligning with findings from previous studies on similar topics. The test results showed a significant increase in participants' knowledge and confidence when comparing pre- and post-test scores.

However, this study did not assess long-term retention of the acquired knowledge and confidence, leaving it uncertain whether these gains are retained over time. Furthermore, the relatively small sample size of participants ($N = 20$) limits the certainty of the findings. Increasing the number of participants would provide more robust data and stronger evidence. Additionally, no participants under the age of 23 or above 31 were included, so the applicability of this VR experience for teenagers/children or adults/seniors remains unknown.

For future development, this VR experience would benefit from refining the interactions to make them smoother and less buggy, as well as expanding the content to include a broader range of first aid topics, such as additional scenarios, AED usage, choking, car crashes, etc., creating an all-around comprehensive first aid VR training tool.

Moreover, tailoring scenarios, graphics, and content to be age-appropriate could make the VR experience a valuable, cost-effective alternative for schools and organizations seeking to provide first aid training, thereby increasing overall public safety. This project demonstrates promising potential in this regard, but further development and rigorous testing are necessary to fully validate its effectiveness.

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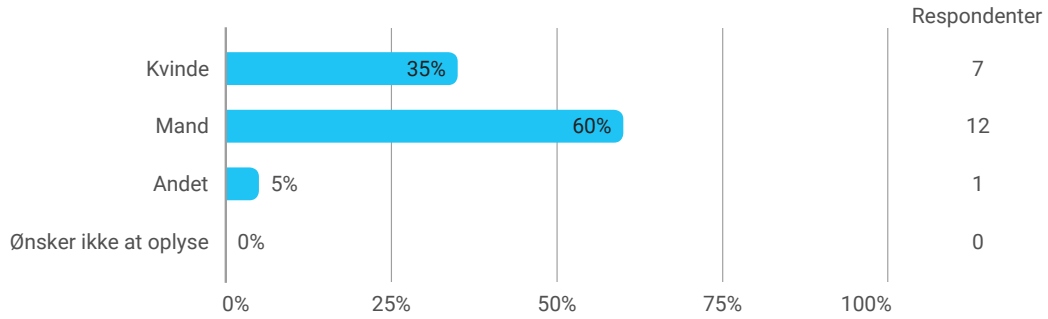
A Full pre- and post-questionnaire questions and results

Angiv venligst dit køn



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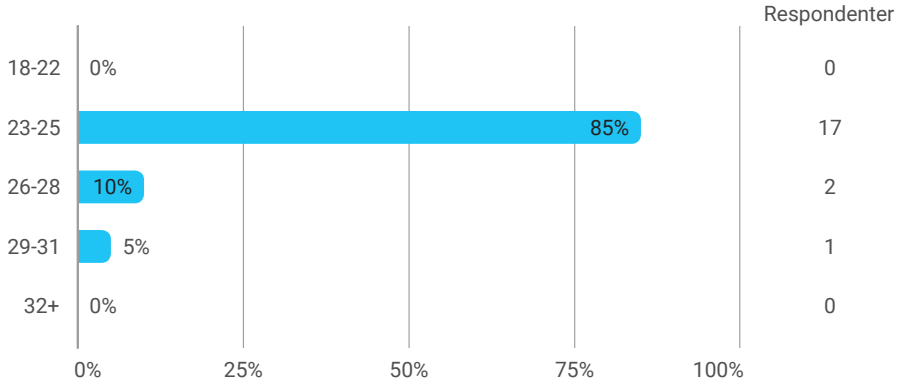
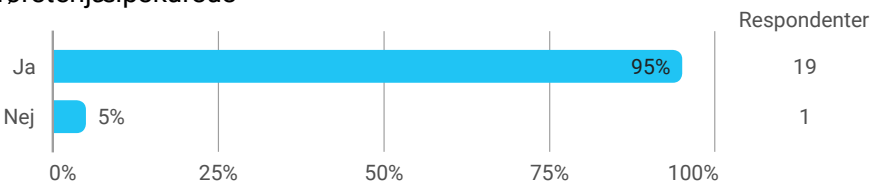
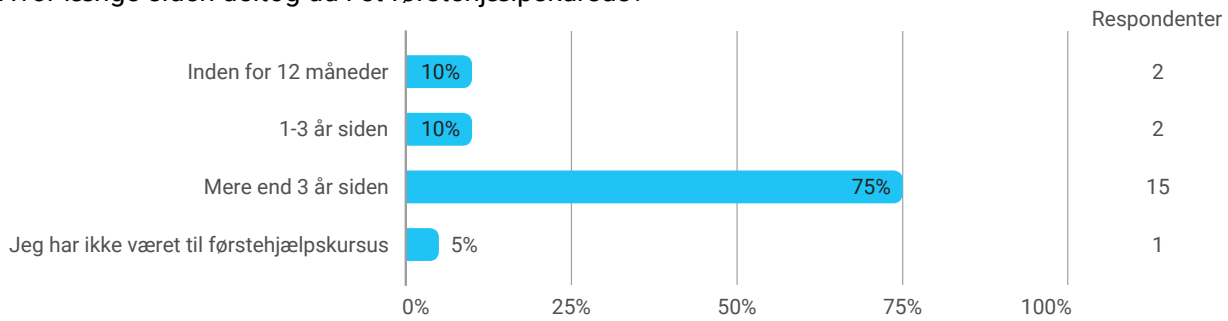


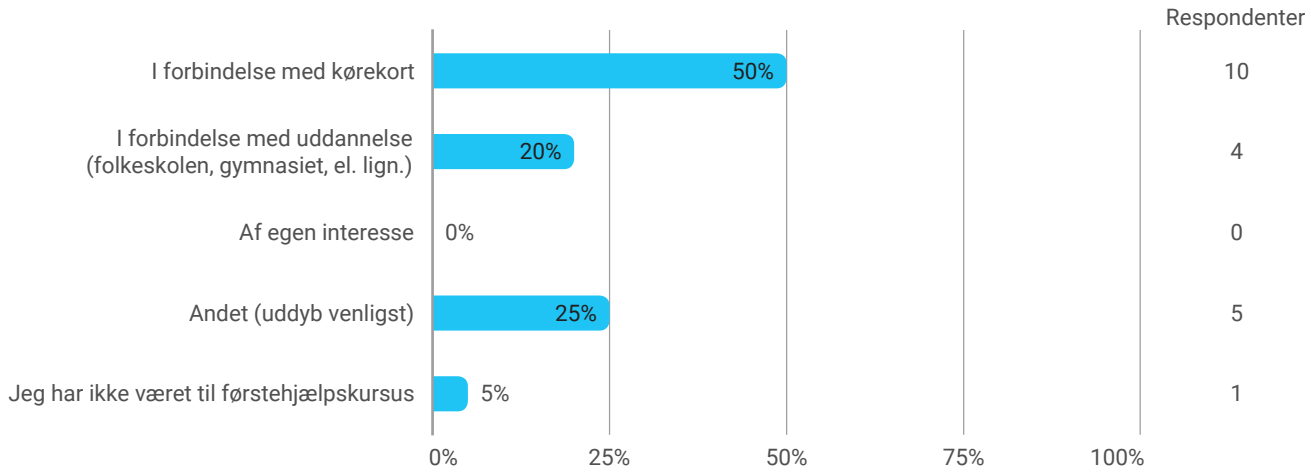
Har du tidligere deltaget i et førstehjælpskursus



Hvor længe siden deltog du i et førstehjælpskursus?



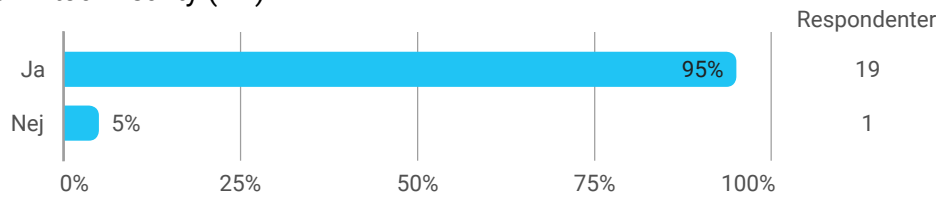
I hvilken anledning deltog du i et førstehjælpskursus?



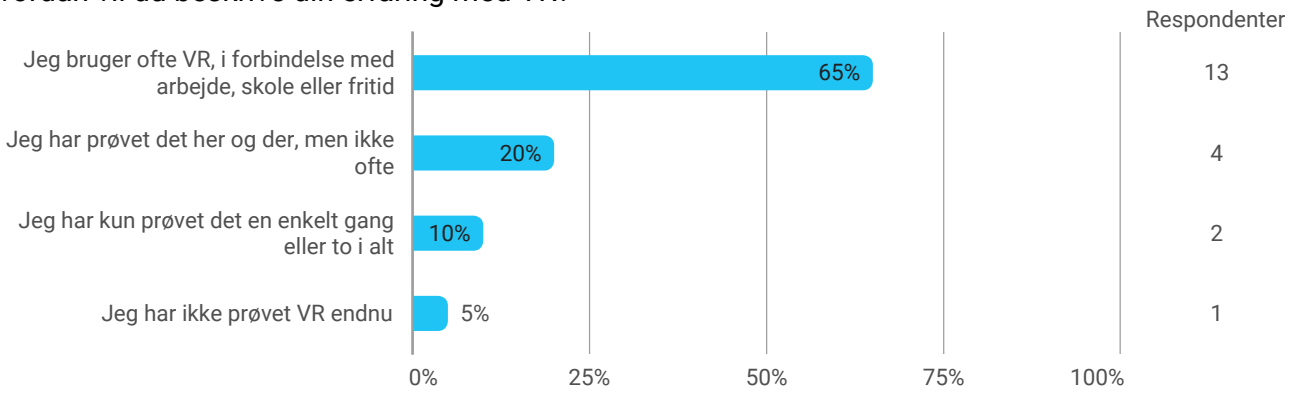
I hvilken anledning deltog du i et førstehjælpskursus? - Andet (uddyb venligst)

- I forbindelse med at blive tutor.
- Som forberedelse til et større event som location organizer (Nordic Game Jam)
- Arbejde
- Nordic game jam/arbejde
- Tutor på studie

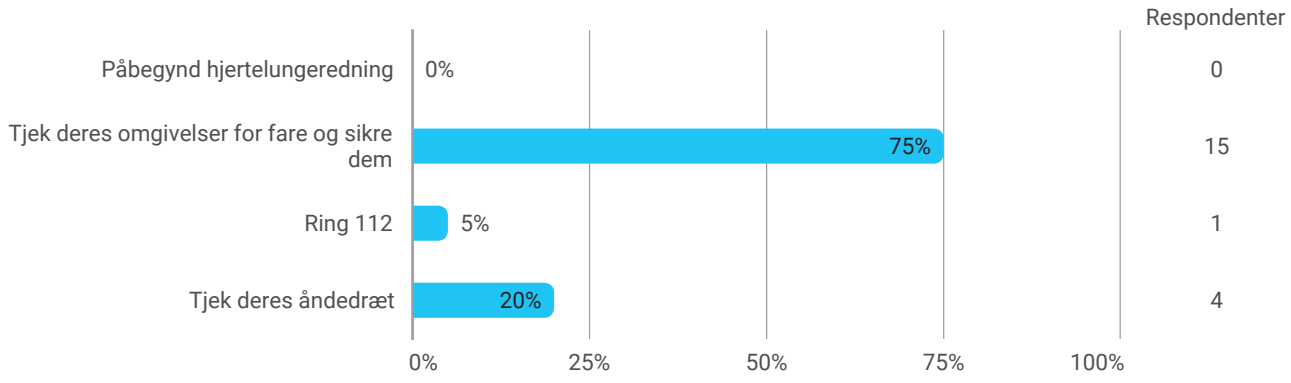
Har du tidligere erfaring med Virtual Reality (VR)?



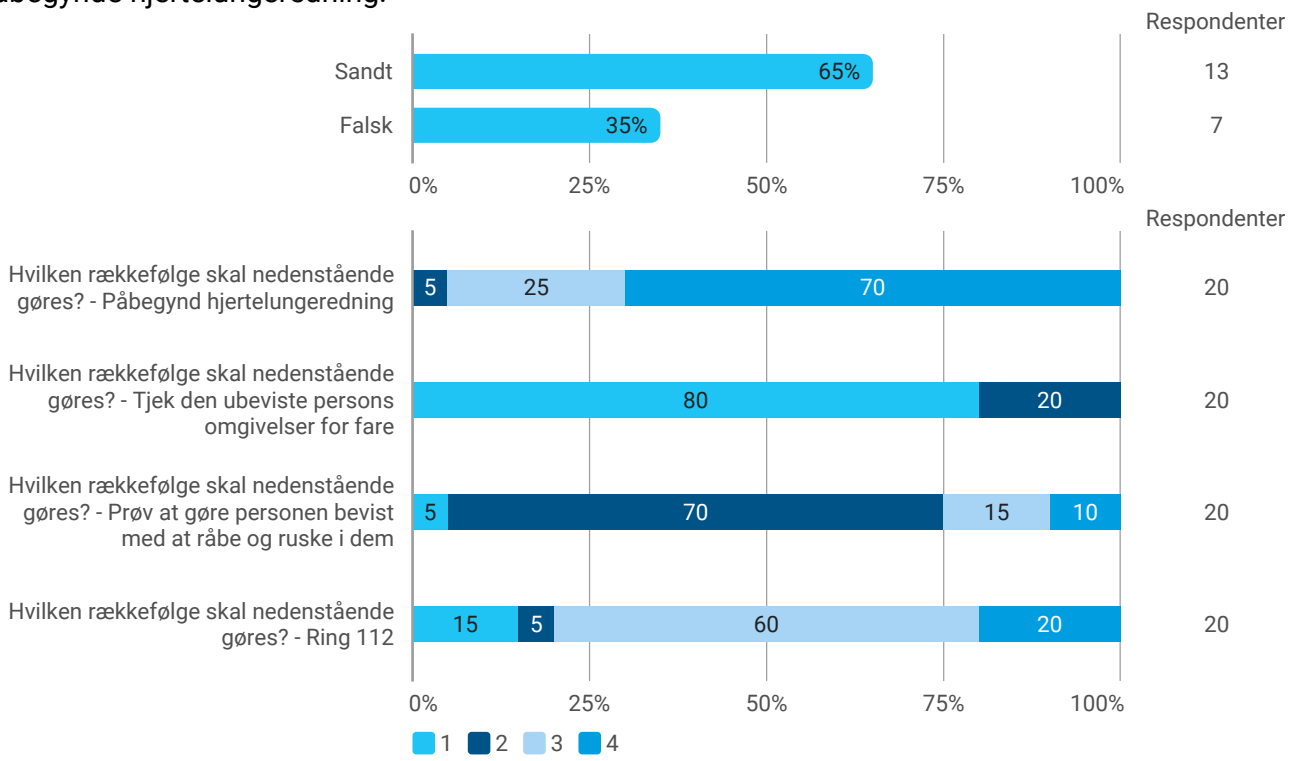
Hvordan vil du beskrive din erfaring med VR?



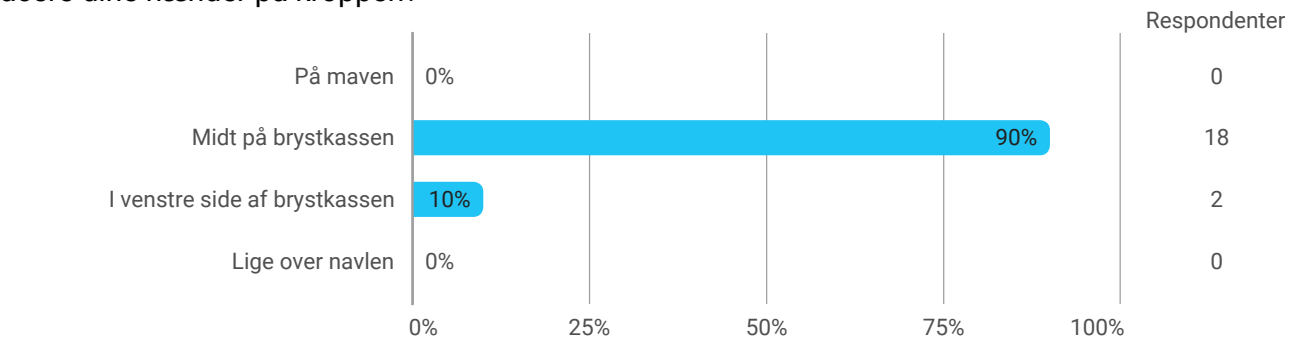
Når du ser en ubevidst person på gaden, hvad er så det første du skal gøre?



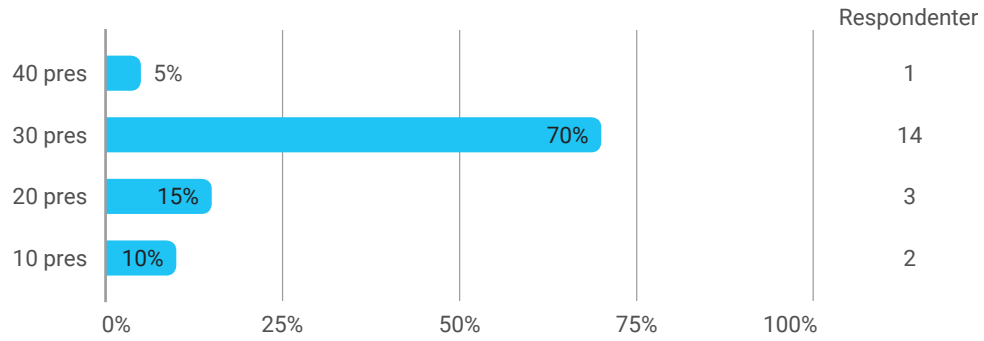
Hvis den ubeviste person ikke trækker vejret korrekt, skal man ringe til 112 med det samme og så påbegynde hjertelungeredning.



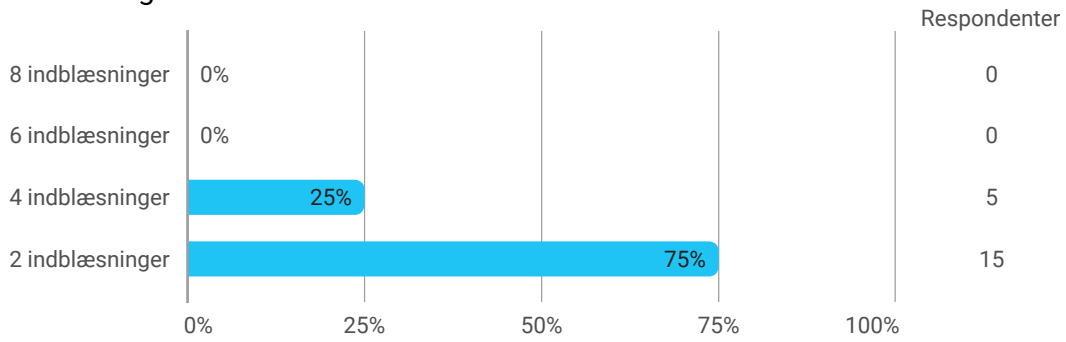
Når du skal påbegynde hjertelungeredning og skal til at lave hjertemassage, hvor skal du så placere dine hænder på kroppen?



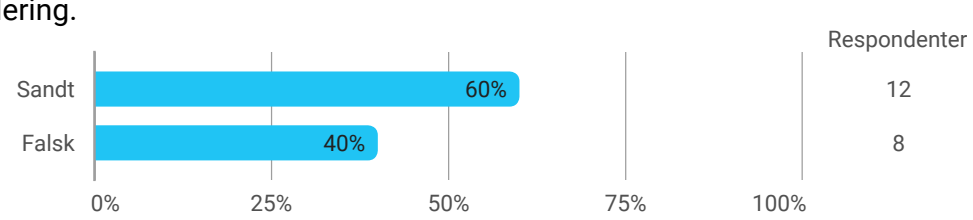
Når du er i gang med hjertelungeredning, hvor mange gange skal du presse før du skifter til indblæsninger?



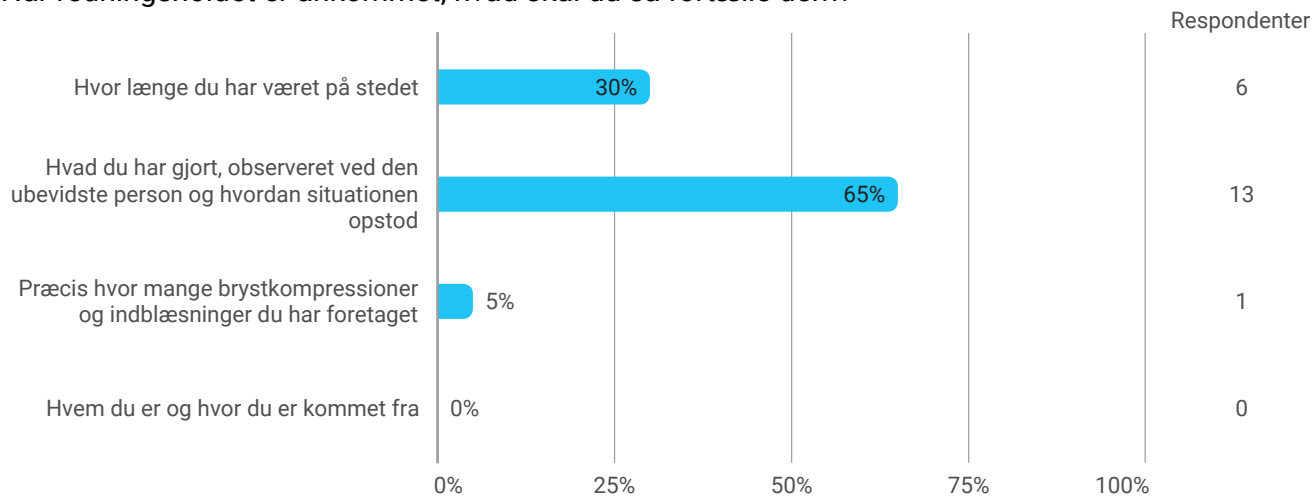
Når du er i gang med hjertelungeredning, hvor mange gange skal du lave indblæsninger før du skifter tilbage til hjertemassage?

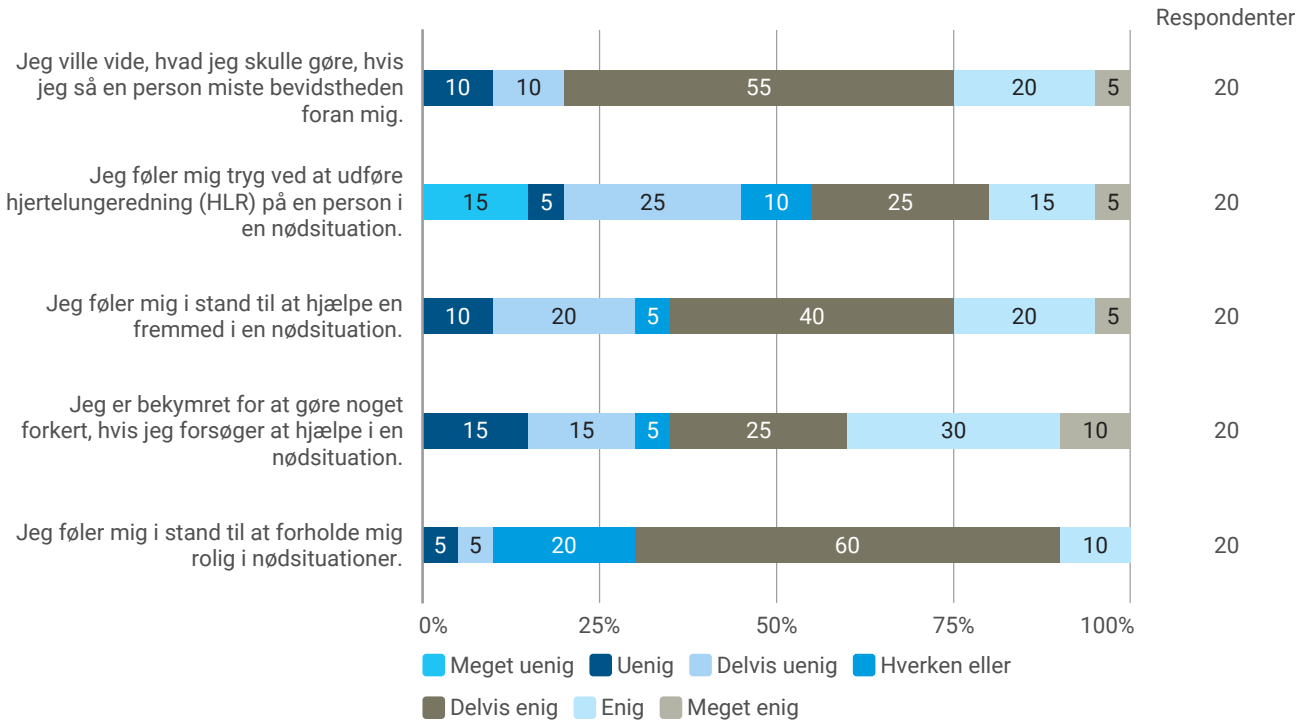


Når du laver hjertemassage, er det vigtigt at brystkassen får lov til at udvide sig helt, da det indikere korrekt blodcirkulering.

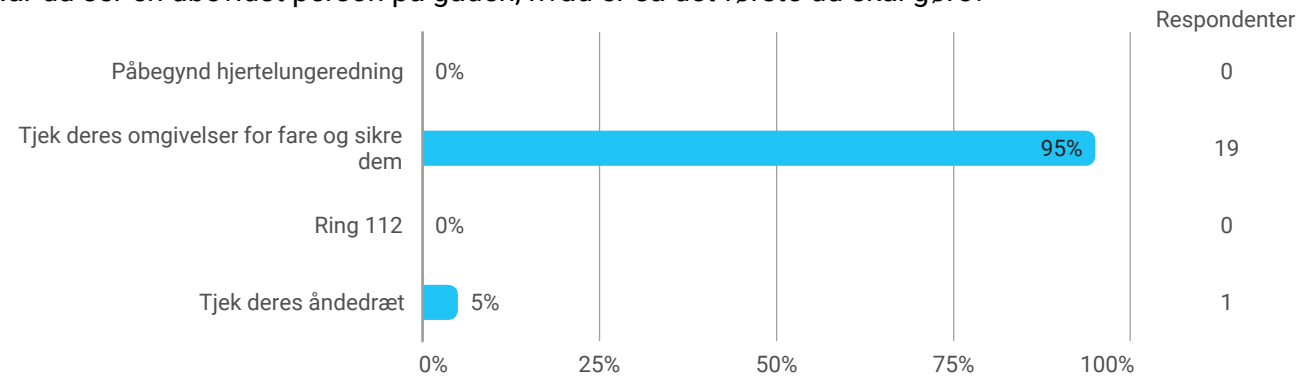


Når redningsholdet er ankommet, hvad skal du så fortælle dem?

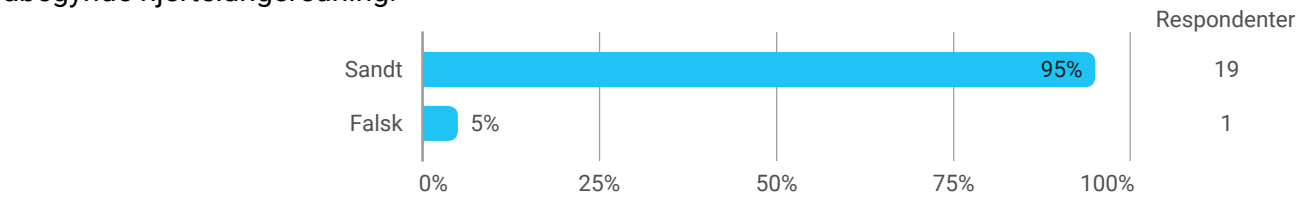


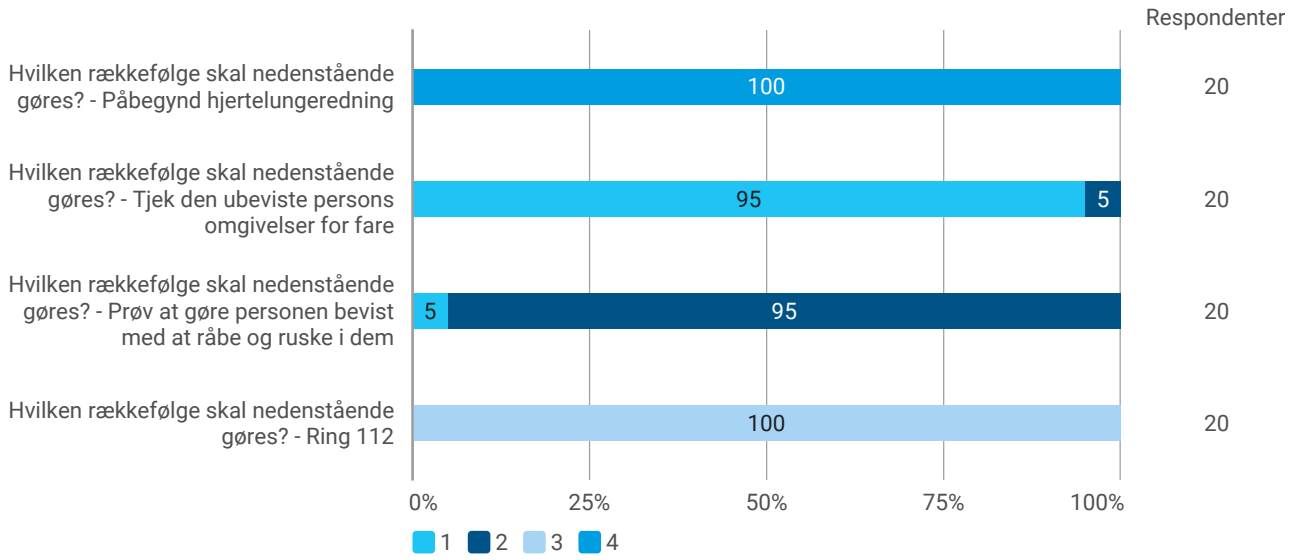


Når du ser en ubevidst person på gaden, hvad er så det første du skal gøre?

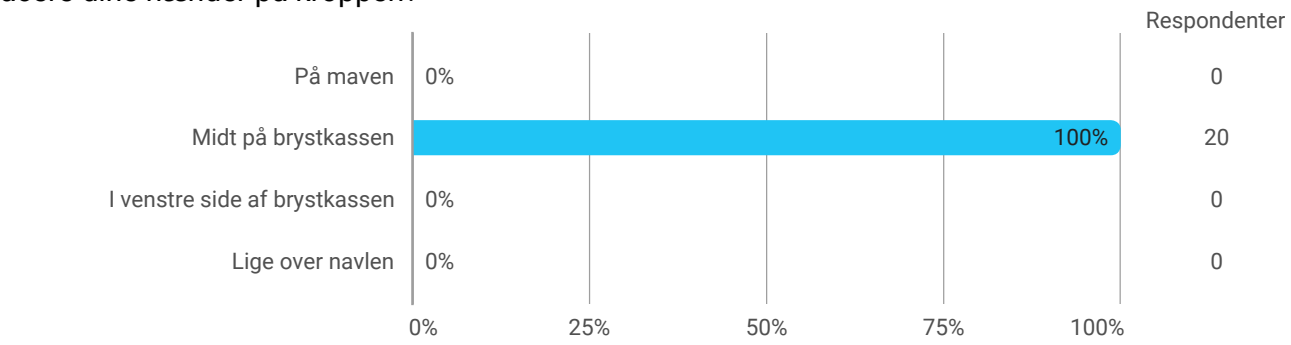


Hvis den ubeviste person ikke trækker vejret korrekt, skal man ringe til 112 med det samme og så påbegynde hjertelungeredning.

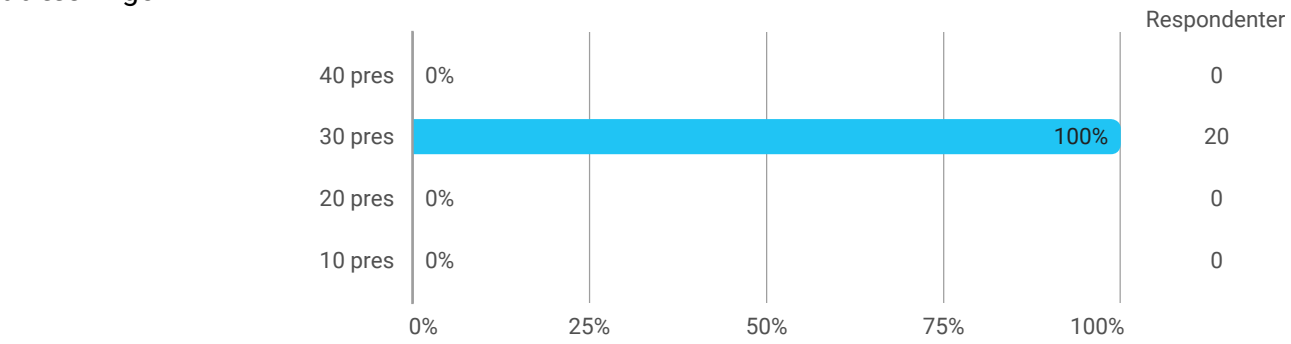




Når du skal påbegynde hjertelungeredning og skal til at lave hjertemassage, hvor skal du så placere dine hænder på kroppen?



Når du er i gang med hjertelungeredning, hvor mange gange skal du presse før du skifter til indblæsninger?



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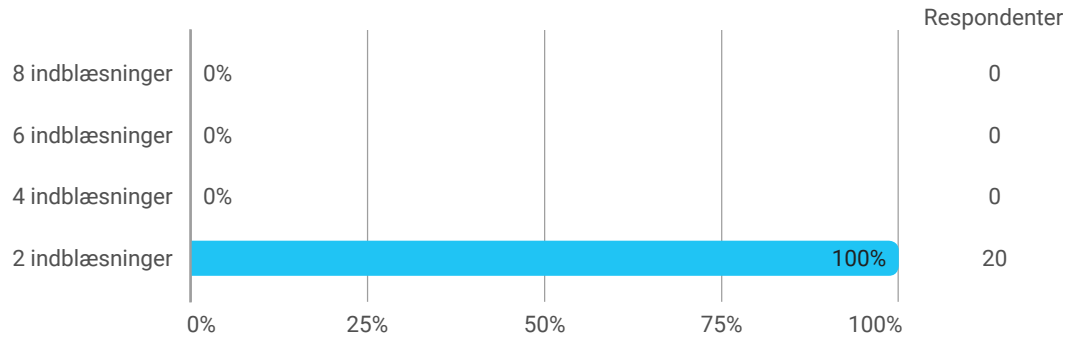
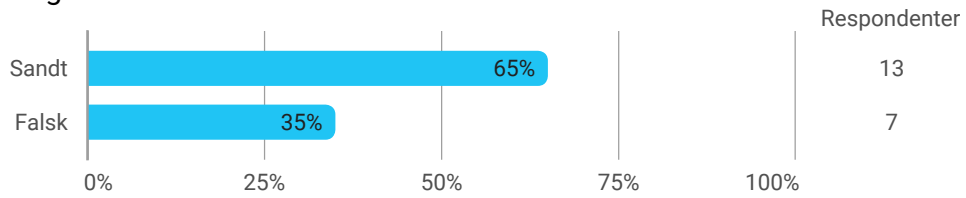
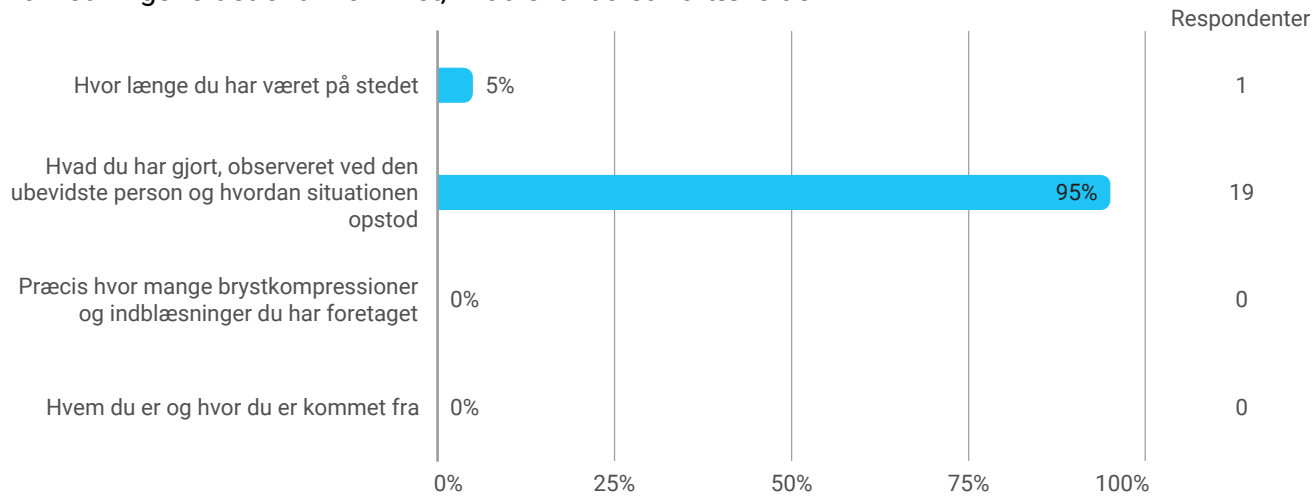
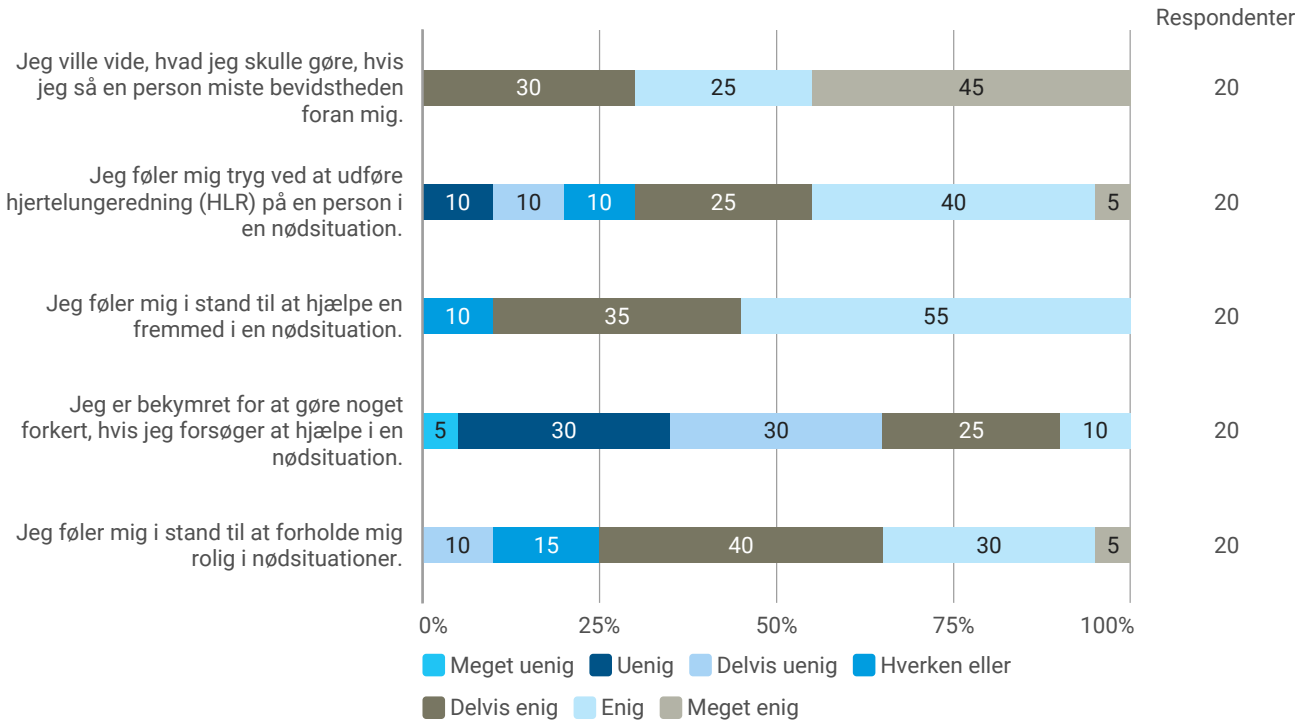


Når du laver hjertemassage, er det vigtigt at brystkassen får lov til at udvide sig helt, da det indikere korrekt blodcirkulering.



Når redningsholdet er ankommet, hvad skal du så fortælle dem?





Er der noget du fandt positivt ved denne oplevelse?

- Information der bliver pålagt. Nemt at følge med.
- God interaktion med personen, kunne dog være fedt med brug af mikrofon input.
- Det er sat realistisk op, især fordi man er den eneste til stede, man for følelsen af at være nødt til at hjælpe fordi andre ikke er til stede
- Det var godt med at den havde BPM til at følge når man skulle lave hjertemassage på dem, gjorde det lettere for mig at ikke gøre det for hurtigt eller langsomt.
- Det var meget pædagogisk lavet, alt var beskrevet godt og det var meget klart hvad jeg skulle gøre og hvordan.
- Jeg synes hele oplevelsen var simpel og intuitiv, og fungerede godt uden fejl. For mig fungerede oplevelsen som en god opfrisker og gjorde mig mere selvsikker i mine egne evner. Det var fedt at det ikke bare var et spørgeskema med rigtig/forkert, men at man også får lov at prøve tingene af i en simulering. Desuden kunne jeg rigtig godt lide at der var den der ting til at hjælpe en med at holde den rigtige rytme.
- Jeg synes, at det var meget positivt at der var en rytme man kunne følge, når man gav hjertemassage, så man var sikker på, at man var konstant.
- Det var skønt at finde sig i situationen så man kunne prøve det, uden at nogen rent faktisk skulle lide et uheld for det, eller at man skulle give mund til mund til en klam dukke
- God gennemgang af de trin man skal tage i en nødsituation.
  god forklaring af hvordan man laver hjertemassage.
- Rimelig nemt at forstå hvad man skulle.
- Det var postitivt at det var forholdsvis simple mechanics og omgivelser så selve livredningen var i fokus
- at man oplever et "realistisk" scenarie, hvor man også tilkalder hjælp, men også at det ikke er at bare give HLR en gang, men gentagende gange
- Det hjalp at visualisere hvordan en nødsituation kunne se ud, og rækkefølgen af skridt
- Selve user journeyen var intuitiv at følge.
- Repitation af førstehjælp, gik over alt det relevente
- Lydene og det simple setup. Overall nemt at forstå hvad man skulle gøre og sådan
- Jeg synes øvelsen var virkelig sjov og god til at forklare på en let tilgængelig måde som alle kunne være med på. Jeg er selv ordblind og synes godt at sådan nogle ting her kan være meget tunge, men det var muligt for mig at kunne være med.
- Rigtig gode informationer der bliver givet, og en god måde de bliver givet på
- Oplevelsen var megret responsive
- Forklaringerne og teksten var nem at læse og forstå hvilket er sjælent i VR

Er der noget du fandt negativt ved denne oplevelse?

- Nej

- Det var lag da ambulancen begyndte at komme, og det at man kunne roterer imens man gav førstehjælp var ret disorienterende
- Ikke andet end få techincal bugs. Det kunne være fint hvis oplevelsen fortsatte en smule længere så man så CPR holder tage over (bunch of animation work tho)
- Åndedråt systemet kunne godt bruge en lille clean up. Var usikker på hvor lang tid man skulle gøre det.
- Ikke rigtig, synes det hele virkede meget godt.
- Næh
- Telefonen var list svær at nå :)
- småting, lidt drilleri/uklarhed med controls men intet en hurtig opdatering ikke ville kunne fikse
- lidt svært at forstå hvor tæt man skulle være på munden når man skulle give nødhjælp. (men kun i vr, i den virkelige verden giverdet mening.)
  lidt svært at bruge mobil telefonen korrekt. men i forforhold til at det er en simulation af hvad man skal gøre, gav det stadig god mening i forhold til de ting man skulle gøre med mobilen.
- Kunne godt have tænkt mig lidt mere feedback fra applikationen i forhold til om man gør ting rigtigt.
- Ikke umiddelbart, men jeg bliver lidt cyber sick når man ikke bevæger sig fysisk rundt i VR, men bruger controllere.
- nej
- Det føltes lidt janky at interegere med manden.
- Der var mangel på feedback ved lunge, + hjerte.
- Det fysiske feedback mangler i forhold til en dukke
- Lidt svært at skulle tjekke op ofte og læse hvad der nu skulle gøres.
- Ikke rigtig, det eneste var, at jeg ikke er så kendt med VR og havde svært ved at finde ud af, hvordan jeg rent praktisk udførte tingene, selvom det var grundigt forklaret, hvordan de skulle udføres.
- Havde svært ved at kigge op på teksten mens jeg lavede CPR
- ingen teleport :(

Har du nogle eventuelle kommentarere til dette forsøg? Kan være forbedringer, bekymringer, osv.

- Synes det var godt
- Mikrofon input mostly. Ellers fed oplevelse
- Det kunne være fint hvis personen lå halvt ude på vejen så man skulle trække ham ind først, hjælper med at sørge for at man ved omgivelserne skal være sikre.
- Nej :)
- Når jeg skulle trykke på brystet skulle controllerne meget tæt på hinanden, og det var ikke hver gang at det lige virkede med det samme. Radiussen for hvor tæt controllerne skal på hinanden før at hænderne får den rigtige placering, kunne godt være lidt større, da jeg følte at de skulle ramme hinanden før at det virkede ordentligt.
- Måske kunne man have instrukserne nede ved hånden eller ved siden af personen, når man skulle i gang med HLR, så man ikke skulle kigge væk, hver gang man hørte lyden der indikerede, at der var nye instrukser. Ellers var det rigtig godt udført :)
- Mægtig fint projekt :)
- lidt mere indikiation på om man gør det rigitigt. altså om man giver hjertemassage i den rigtige rytme of dybt nok, og om man giver ilt når ens hoved er tæt på mandens mund.
- Kan føles lidt "akavet" at skulle gøre disse ting især når der er folk der kigger. Ved ikke om folk ville kunne leve sig mere ind i det hvis de var alene i et rum imens de prøvede appen.
- jeg synes det var en god oplevelse og kan kalrt også bruge i andre sammenhænge som træning osv :)
- Informer om at man ikke skal stoppe når ambulancen kommer, men først når rednings folkene sige man skal eller personen vågner
- Kunne være lidt nemmere for brugeren hvis informationen var tæt på det man lavede. Nogen af delene af det var lidt "clunky" og føltes dårligt at bruge. Kunne bruge en smule refinement og sørge for at "gameplayet" kørte lidt nemmere. Fx ved der hvor man skulle puste var det lidt svært at vide hvorår det var rigtigt eller forkert.
- Jeg var bekymret til at starte med for, at jeg ikke ville kunne have tid til at finde ud af, hvordan man udførte selve funktionerne på VR, når det skal simulere at dør. Det var rart, at man havde tid til hver episode af situationen uden, at der var tidsbegrænsning på.
- Eventuelt ryk teksten eller vise at man godt lige kan tage sin tid til at se op