Exploring Technology For Neonatal Resuscitation Training

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ABSTRACT

The healthcare industry is regularly seeking for innovative ways to leverage technology in order to create or improve the experiences of their professionals and their patients. With advancements in Head-worn display (HWD) technology such as the Microsoft Hololens, we must look into the feasibility of leveraging the technology to aid us in the ongoing challenge of creating these meaningful and educational experiences. In this research, by targeting the *bag and mask* step in the Neonatal Resuscitation training, we evaluate the efficiency and performance of using data from sensor devices and immersive technology to help provide users with useful feedback. Two studies were conducted to evaluate the potential of these technologies as well as the most effective method of delivering the feedback. We have found that between four different stimuli, a visual stimulus resulted in the best performance in the timing of the bag compressions in both our studies with non-healthcare professionals and healthcare professionals. Based on the results of the study, we also express the importance of having a proper seal between the mask and the baby in order to achieve the appropriate pressure during manual ventilation.

CCS CONCEPTS

• **Human-centered computing** → *Empirical studies in HCI*.

KEYWORDS

healthcare, augmented reality, gamification

ACM Reference Format:
Kenny Hong, Yumiko Sakamoto, Ganesh Srinivasan, and Pourang Irani. 2020. Exploring Technology For Neonatal Resuscitation Training. In *11th Augmented Human International Conference (AH '20), May 27–29, 2020, Winnipeg, MB, Canada.* ACM, New York, NY, USA, 9 pages. https://doi.org/10.1145/3396339.3396359

AH '20, May 27–29, 2020, Winnipeg, MB, Canada

ACM ISBN 978-1-4503-7728-7/20/05…$15.00
https://doi.org/10.1145/3396339.3396359

1 INTRODUCTION

This research investigates a means to improve the performance of an intricate and precise procedural task, namely, neonatal resuscitation, by utilizing external devices to capture user activity and visually and/or auditorily presenting their performance. The *bag and mask* step is an important and yet difficult part of the of neonatal resuscitation procedure [31]. The steps to perform the bag and mask procedure need to be followed accurately. In this research, we explore if there is a significant difference in users' performance depending on four different types of stimuli which convey feedback from a Phidget air pressure sensor [20] which is one the bagging device. Subsequently, we plan to leverage a Mixed Reality (MR) Head-worn display (HWD), a device used in a variety of modern healthcare training, to provide the information to the user and observe the effects of using the HWD.

Procedural tasks such as positive pressure ventilation (PPV) (or the bag and mask step) require a set of step by step instructions in general. If the task at hand is complex, the instructions need to be simple in order to reduce the cognitive load. Indeed, various medical procedures often consist of numerous complicated steps and, thus, are challenging. We believe that having new technology, which allows users to 1) view crucial data, as well as 2) view the feedback of their performance while they are executing this procedural task, will enhance their task performance significantly. By using a modern wearable MR device such as the Hololens, various types of useful/critical information can be provided consistently across multiple areas in an assistive information space. By leveraging the new HWD's spatial mapping and positional tracking technology, maintaining consistent positioning of the information space layout is achievable. Thus, by providing the user with essential information concerning their task (e.g., instruction) and supplementary data, theoretically, it is possible to reduce the users' cognitive load to facilitate their performance.

We have reviewed the standard manual for the Neonatal Resuscitation Program: Textbook of Neonatal Resuscitation (NRP), 7th Edition [31], and identified the essential elements for successful PPV, and implemented a tool in order to gauge the performance of both laypeople and healthcare professionals. The full apparatus consisted of a modified resuscitator equipped with a gas pressure Phidget sensor, and the Hololens. To incorporate our stimuli and to gauge performance, we looked into the concept of gamification and implemented a game on the Hololens. Through two studies, we

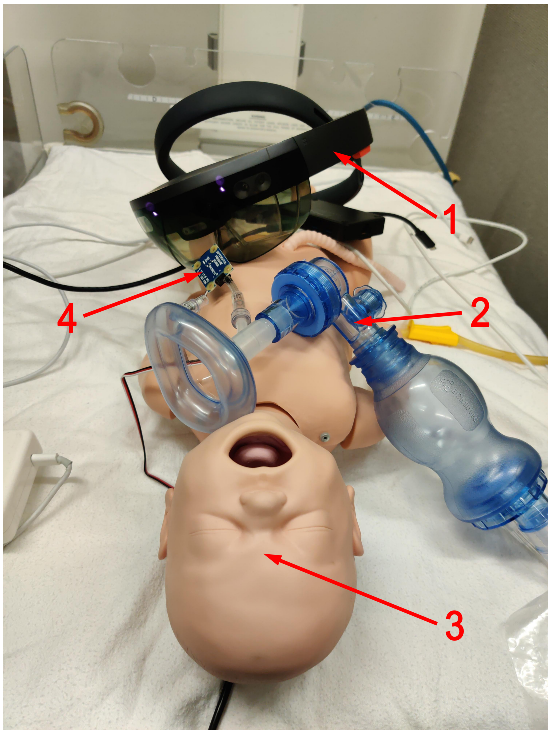


Figure 1: Equipment used for the studies. 1. Hololens, 2. BOMIMed Disposible Ventilator, 3. eNasco Life/Form Newborn Simulator manikin, 4. Phidget gas sensor

explored the use of our tool and the performance between laypeople(i.e., non-health-care experts) and health-care experts such as nurses, doctors, and respiratory therapists. In the first study, we test the apparatus with laypeople using either visual, audio, a combination of the two stimuli, or a visual and audio stimuli that transitions into audio only to investigate the performance of multiple areas of the PPV step. These areas include: compression timing, pressure accuracy, and achieving both at the same time. In the second study, we reproduce the same study with health-care professionals to validate the findings in the first study. Our results reveal that the visual stimulus is better than the audio stimulus with regards to compression timing over both studies. We also find that, overall, pressure accuracy is more difficult to control than the compression timing. Our contributions include (1) an exploration into using technology such as the Hololens for practical training in PPV and (2) a potential tool for frequent and accessible training.

2 RELATED WORK

2.1 Neonatal Resuscitation and Current Tools

Out of an estimated 136 million babies born annually, roughly 10 million newborns require assistance to breathe, and 6 million of the affected newborns require basic bag and mask resuscitation [26]. The bag and mask step is required to provide assisted ventilation through a face-mask [31]. Although it is critical that this step is performed accurately and smoothly [31], this step is quite challenging. Previous work has shown that many improvements need be made to the bag and mask step to improve its performance [10]. One significant aspect that can be improved is the training of the neonatal resuscitation procedure [39]. Examples of current methodology for neonatal resuscitation training range from basic scenario training (e.g., following step-wise instructions in the textbook on a manikin) [31] to delivery-room simulations with full auditory/visual feedback [18]. Further, research done by Rubio et al. has shown that in-situ simulation training can provide positive results in improving technical skills and teamwork in neonatal resuscitation [37]. In North America, the renewal of the neonatal resuscitation training is required for healthcare professionals every two years with a goal to maintain adequate level of care when an infant requires resuscitation [15]. These skills have been shown to degrade by 3–6 months. This work will look into using new technology to improve the current training available further and potentially provide more frequent training for the bag and mask step of the procedure by developing a tool that is both accessible and available at any given time.

2.2 The Importance of Bag, Masks, and PPV

While the lives of many newborns depend on mechanically assisted ventilation, using mechanical ventilation can cause potential long term pulmonary complications such as volutrauma [1]. The risk of this type of injury when exposed to mechanical ventilation is higher in preterm infants. The majority of preterm babies are born at less than 28 weeks' gestational age. Moreover, these infants are the most vulnerable and require PPV in the delivery room [32], resulting in a shift for maintaining neonates with more non-invasive ventilation such as using face masks for PPV [42]. Weydig et al. note that with non-invasive ventilation being the preferred choice for low gestational age infants, the effectiveness of face mask PPV hinges on the professional's ability to detect and overcome mask leaks and airway obstructions [42].

2.3 Situated Learning

Situated learning is described as learning through scenarios embedded within the social and physical environment where the situation occurs [25, 34]. The use of situated learning or learning in-situ varies across disciplines. In Computer Science, the term in-situ, specifically in user interfaces, is primarily defined as continuously providing an user access to relevant information in various locations and contexts [16]. In the medical field, in-situ training often takes place on-site and uses real scenarios in order to train the professionals [41]. In other disciplines, in-situ training can be done through simulations. For this work, in-situ will be in the context of Computer Science's definition. Specifically, this research will explore different ways to deliver feedback to users while they are training in-situ.

2.4 Skill Retention

With regards to skill retention, an important topic of discussion for decades has been the quality of the skill over time. Within neonatal resuscitation, evaluations have shown that, although general knowledge is retained, the proficiency of the skills deteriorate indicating that proficiency in knowledge may not be related to the quality of the skill necessarily [35]. Simulation training has been shown to help the performance in neonatal resuscitation [8, 30]. However, without any proper refresher training, the level of performance degrades over time.

2.5 Augmented Reality as a Tool

AR systems are defined as systems that enable real time interactions with virtual and real objects that coexist in the same space [4]. These systems come in many different forms such as head-worn displays, projections, and mobile devices that allow you to view virtual objects in the real world. Unlike VR, AR allows for a digital experience in a real environment rather than a fully virtual environment. In some cases, interactions within an AR environment are more advantageous than the VR environment [23]. Bower et al. [6] highlight the usage of mobile phones and tablets to overlay media onto the real world in order to make information available to students when they need it, on the spot. Bower et al. discuss the potential reduction of cognitive overload by providing students real time information. AR has also been used within the health-care field, specifically the medical field, where it is used for training in various medical tasks and procedures.

This work used HWDs such as the Microsoft Hololens [29], a new headset that enables users to interact with virtual objects in the real world. Combined with the concept of situated learning, where Brown et al. suggest that learning should take place in the context of realistic settings [9], the Hololens may have a factor in providing users with the necessary information required during training in-situ. By providing users with additional information when they perform these procedural tasks, they are given the necessary feedback to enable them to adjust their execution in order to potentially improve their performance. This will in turn, allow them to learn in an authentic context [12, 28].

2.6 Simulations Using Augmented Reality

Previous work investigated the use of AR in order to improve health-care related procedures such as surgical navigation. Both Okamoto et al. [33] and Chen et al. [11] developed AR-based simulations with the aim to improve the safety and reliability of surgery. They verified and demonstrated that the accuracy of their application was sufficient to meet clinical requirements. However, this is so far only true with a simulated environment. Within the same area of study, Pratt et al. [36] looked at how the use of the Hololens in order to provide a means of bringing a new level of precision and planning into reconstructive surgery. Through preliminary studies, the authors were able to demonstrate that using the HWD could help with the precise localization of perforating vessels.

2.7 Gamification of Training

Gamification can be described as a method of applying the typical elements of game playing, such as scoring systems and competitive leaderboards, to other areas [27]. MacKinnon et al. [27] has found that gamification can improve infant CPR performance. Their motivation to explore the use of competition as a gamification technique stems from the lack of methods to "motivate frequent and persistent CPR practice". By using the ventilation and compression scores calculated from a Laerdal Infant QCPR manikin [24], the authors created a leaderboard system to motivate competitive behaviour and motivate frequent use to improve on their performance and achieve a higher score. In this work, we create our own system using a common resuscitator found in healthcare facilities with modifications to detect pressure.

The use of serious games has also been looked at to teach medical students a variety of situations. For instance, work has been done in areas such as decision making in team situations [7, 40], surgery [13, 14], and various triage assessment scenarios [2, 19]. Bergeron [5] also suggests that serious games can improve skill retention. However, Kaczmarczyk et al. [22] have reported that further empirical research is required to assess the added value of gamifying medical training.

3 METHODOLOGY

In this section, the critical requirements for successful PPV are laid out based on the literature [31]. Moreover, this section will outline the design and implementation of the apparatus used as well as the studies conducted.

3.1 Research Questions

Two research questions were created to drive the focus of the research and explore the value of this training:

- *RQ*1: Do different stimuli induce different levels of learning?
- *RQ*2: Are participants able to perform the procedure given the specific instructions?

3.2 Defining Application Requirements

Based on the literature, we outline aspects of PPV that define the requirements of the application used for the study. In order to simulate PPV, the NRP textbook [31] provided us the standards of PPV.

- Positioning: Proper positioning of the baby's head is required for effective mask ventilation. Incorrect positioning will obstruct the airway.
- Mask: There are a variety of mask sizes available. Selecting the correct mask will create a tight seal on the baby's face preventing air leaks.
- Pressure: Achieving the correct pressure is significant during PPV. If the pressure of the compression is low, it may not be enough to inflate the lungs; however, if the pressure is too high, it may burst the lungs of the newborn.
- Timing and Rhythm: The timing of the bag compressions is also important for en effective PPV.

3.3 Apparatus

3.3.1 The Resuscitator. For this research, we used a RespondPro Manual Rescucitor, a self-inflating bag, manufactured by BOMIMed (see Figure 1). This disposable bag is standard in most hospitals in North America and was used for this study [31]. Furthermore, the mask selected for this experiment was a teardrop-shaped mask that came with the bag; this fits the manikin used for the studies conducted.

A T-piece was attached to the tube where the mask would be placed before the mask was attached. The T-piece was added in order to attach a small tube with a gas sensor Phidget (P/N 1139)

[20] to the T-piece to measure the compression pressure for the study (see Figure 1). Unnecessary tubing attached to the back to the resuscitator was cut off in order to reduce clutter and interference when being used.

3.3.2 Baby Manikin for Resuscitating. The manikin used for this research was the eNasco Life/Form Newborn Simulator manikin (Figure 1). The manikin would be placed on a bed, as described in the textbook during the study. This manikin was not modified; all modifications for measurements in this research were made on the resuscitator.

3.3.3 Head-worn Display. The potential of AR HWDs is explored in this research. The motivation to use an AR device was to create a training simulator that was portable and can be used anywhere. HWDs can display essential data and information in a virtual space. Moreover, information divided among multiple screens and monitors can be compiled and displayed virtually on the HWD, eliminating the need for those monitors and allowing for portable experiences that still provide the necessary information.

There are many HWDs available to display information; however, the hardware that stood out as the best choice was Microsoft's Hololens [29]. At the start of this research, the first generation Hololens was the best selection in terms of augmented reality experience. The Hololens has one of the largest fields of view available for AR devices. This allows for a larger viewing area to display potential information.

3.4 Task Implementation

The task required two applications. The first application captured the data coming from the Phidget and sent it out through a network. The second application was the game created for the Hololens. The game created for this tool used the data communicated from the Phidget application to play.

The data from the Phidget was captured using the Phidget's C# API. For both studies conducted, the Phidget attached to the ventilator was connected to a Macbook Pro 15" Late 2016 model via an USB Hub and then sent to the Hololens through a local network. The Phidget data capturing application is also Windows compatible. The server/client implementation was developed using the NetCoreServer library [38], and the local network consisted of a standalone wireless router that was not connected to the internet. This setup and implementation ensured lower latency and no potential for interference from other devices. Furthermore, the only devices connected to that router were the laptop and the Hololens.

The game was first implemented using Unity 2017.4.12f1 as a desktop application, then ported over to the Hololens using the Mixed Reality ToolKit by Microsoft. No interaction with the Hololens was necessary during the studies. The application was controlled using the ventilator, minimizing the learning time required for the experimental part of the research. The Hololens allowed us to test all the stimuli we were interested in for this research. The design of our game and implementation took into account the PPV procedure outlined in the standard manual [31]. These characteristics greatly influenced the overall design [31]:

- Timing: The rate of bag compressions is 40 breaths per minute. Indeed, the PPV procedure and instructions are much more complicated, however, this research focuses on achieving the correct rate during sessions of compressions.
- Pressure: The target pressure for initial PPV is 20 to 25 cmH_2O. Using the Phidget device attached to the ventilator as explained in the previous section, the device, in Pascals (Pa), can measure the pressure of the airflow coming from the compressions. By converting cmH_2o to Pascals, our target pressure for the implementation was 1961 to 2452 Pa.

In summary, one must achieve the correct timing at the correct pressure with each compression to be effective at PPV.

3.5 Stimuli

We examined the effectiveness of different types of feedback. For the first study, four stimuli were tested with non-healthcare professionals. Based on the results of study 1, then, two most valuable stimuli were chosen and tested with healthcare experts (respiratory therapists, nurses, and doctors in various areas) in Study 2. A simple platform game was implemented to induce four stimuli presented in Study 1:

- Visual: Feedback was provided as the game's visuals attribute, allowing participants to visually recognize the targets and how they can adjust based on the position of the target.
- Audio: Feedback was given as the game's audio attribute, allowing participants to hear the stimuli signaling when to compress the pump and how they can adjust its timing and strength, based on the audio feedback. All the audio feedback used came from freesounds.org [3].
- Visual and Audio: Participants received both stimuli; they were able to see the game's visual while hear the auditory feedback.
- VATransition: Participants received only visual feedback in the first half then switched to auditory feedback alone, midway.

3.5.1 Visual Stimuli. Participants in the visual stimuli condition (visual, visual+audio, VATransition), saw a two-dimensional 8-bit fox run across a platform (see Figure 2). Every 2.5 seconds, a target in the form of a wooden crate spawned, and the objective was to compress the ventilator to make the fox jump to hit the crate.

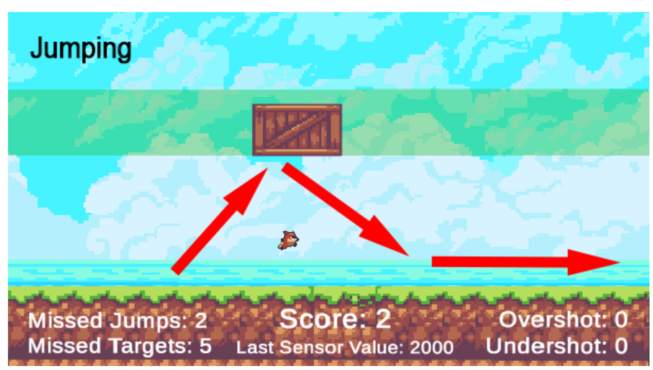
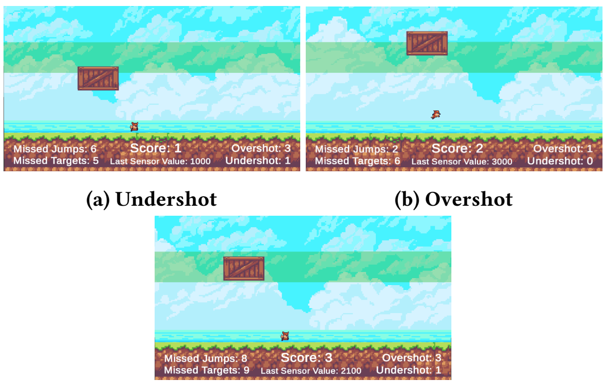


Figure 2: Basic movement concepts of the application

The height of the jump depended on the amount of pressure exerted on the ventilator. A green area was shown in the game to identify the target range of the pressure. Anything over or under the green space was an over-shot or an under-shot, respectively. Participants saw a scoreboard that gave the score, the number of over-shots, the number of under-shots, missed targets, and the previous compression's pressure. The scoreboard allowed the participants to adjust continuously based on their performance (Figure 3).



(a) Undershot **(b) Overshot**

(c) Score

Figure 3: Possible outcomes when compression timing is correct

3.5.2 Audio Stimuli. All of the mechanics of the visual stimuli were also associated with audio feedback. The audio cues were chosen based on discussions with advisors for this application. The sounds had to be carefully selected to be effective. When the participant scores, the tone must sound rewarding. However, negative tones must sound like alerts to inform the participant to make adjustments. Neutral tones such as the jump signal must be clear and not rush the participant into compressing the bag. Before the experiment, participants were able to hear and familiarize themselves with the sounds through a simple soundboard web application. During the audio only conditions, the game would be running in the background, however, the visual was blocked by a mask leaving only the audio cues.

3.5.3 Visual+Audio & VATransition. In the Visual and Audio condition, participants were exposed to both the visual aspect of the game and the associated audio. VATransition took the combination one step further by masking the game after the first half of the study, leaving only the audio feedback. Participants had exposure to both stimuli at the beginning, and then they had to rely on just the audio cues for the second half of the study.

3.6 Study Procedure

A research assistant conducted both studies. For all studies to be consistent, the research assistant used a script. The script included steps such as reviewing and signing the consent form, detailed instructions of the task, and a video tutorial on how to use the ventilator. Participants were randomly assigned to one of the conditions (four for study one and two for study two). For the video conditions, participants were given a video tutorial on the game outlining the basic game-play and instructions. For the audio conditions, the research assistant running the study played the audio feedback for the participants, explaining the meaning of each sound. Once the experiment was complete, the research assistant administered Ishihara's colour vision deficiency test [21] and a questionnaire. Finally, the participant was debriefed and thanked for their time. This research was approved by the Ethics Board at a local university.

3.6.1 Experimental Environment. Both studies were recorded using a GoPro Hero 3+ [17] mounted on a stand that was attached to an infant bed warmer. The recordings captured the participant performing the PPV procedure, without any directly identifying features of the participant (i.e., chest and below was captured).

3.6.2 The Task. The task consisted of twenty trials of twenty compressions, each where the participant had to attempt to squeeze the ventilator with the correct timing with the right pressure. The implementation based the timing of the compressions on the rhythm taught in a commonly used textbook [31]: *"...breath, two, three, breath, two, three,..."*, therefore, each compression is approximately 2.5 seconds apart. Additionally, twenty compressions were given per trial to simulate 40-60 breaths per minute. To minimize participants' fatigue effect at both physical and cognitive level, participants were instructed to take one minute break after every five trials for a total of three breaks. The task is the same across all the conditions. Since all the participants were required to stand during the trials, they were able to sit down during their one minute rest period. Before each trial, a menu screen is displayed with potentially useful information such as a reminder of the target values, the current trial, and the summary of the last trial. A cooldown timer is given to time the participants' breaks.

3.6.3 Instructional Video - PPV. Once the participants claimed they understood the task at hand, the research assistant played the instructional video for bagging and masking. This video featured an experienced respiratory therapist performing the procedure. The video's instructional voice-over was based on the Neonatal Resuscitation Program training sessions.

3.6.4 Post-Study. Upon completion of the study, each participant was asked to take an online version of Ishihara's colour vision deficiency test [21]. The research assistant also administered a general questionnaire, which included general demographics. The Ishihara test provided insight on a potential usability issue while using the Hololens. The participant was then debriefed, thanked, and received an incentive for their time.

4 STUDY RESULTS

In this section, the results are organized by; 1) compression timing, 2) pressure performance, and 3) score for both studies. Out of the twenty trials, trials 1 to 10 were removed from the analysis. The exclusion was due to participants in the VATransition condition having both stimuli in the first half of the study, with one stimulus being removed for the second half. At the 11^{th} trial, the game masked the visual stimuli, thus, leaving only the audio stimuli. Further and importantly, we aimed to give participants sufficient time to practice the task at hand.

4.1 Study 1 - Laypeople

4.1.1 Participants. Forty-one non-healthcare professional participants (15 females) were recruited, one participant (female) began but was not able to complete the study. Subjects' ages ranged from 18 to 49 years old (M = 25.43, SD = 6.70). Experience with medical procedures was not necessary to participate in this study. To simulate a learning experience, we were interested in observing whether or not a non-healthcare professionals could pick up this skill from a healthcare professional and perform the task at hand.

4.1.2 Compression Timing. First, the compression timing component of the participants' performance was investigated. We conducting a Kruskal-Wallis test and a Mann-Whitney U test with the application of the Holm-Bonferroni method was applied throughout the study in multiple comparisons, to accommodate for potential Type 1 errors. Note as the alternative to Bonferroni's correction, where a consistent threshold is applied, Holm-Bonferroni's method progressively adapts the threshold in which hypotheses are rejected based on the ranks of the mean scores of the comparisons.

The Kruskal-Wallis Test found a condition effect: χ^2(Visual+Audio) = 11.64, p= 0.009, with a mean rank accuracy scores of 29.35, 23.30, 16.25, and 13.10 for the Visual, Visual Audio, Audio, and VATransition conditions, respectively. Subsequently, Mann-Whitney U tests were conducted to identify where the difference occurred. These tests found that the Visual condition was significantly better than both the Audio and the VATransition conditions. Between the Visual and the Audio condition, the test found the following effect: U = 15.00, p = .007, (Visual mean rank: 14.00, Audio mean rank: = 7.00) — Holm-Bonferroni α = .008. In the case of Visual and VATransition, the tests found the following effect: U = 16.00, p = .009, (Visual Mean rank: 14.00, VATransition Mean rank: = 7.00) — Holm-Bonferroni α = .01. No other significant effects were found. Visual feedback was found to be most valuable.

4.1.3 Pressure Accuracy. ANOVA was conducted for this section since its assumptions were not violated. No effect was found across all conditions. Pressure accuracy was not influenced by the type of feedback.

4.1.4 Missing Data. The lack of condition effect in pressure accuracy was somewhat surprising. Moreover, upon analyzing the data, many missing values were found: The missing data occurred when no pressure value was recorded. Out of the 16000 total compressions, 3303 values were missing (20.64%). No pressure values are recorded when the Phidget sensor does not capture any pressure when the bag is compressed. This indicated the great difficulty of masking task.

4.1.5 Score. Participants received a point towards their score if their pressure was correct *and* their timing was correct. The Kruskal-Wallis Test found a significant effect: χ^2(Visual+Audio) = 10.61, p= 0.014. Mann-Whitney U tests were further conducted to follow up. Two significant effects emerged. The first, between the Visual (mean rank = 13.80) and the VATransition condition (mean rank = 7.20), p = 0.006 — Holm-Bonferroni adjusted α = 0.01. The second, between the Visual+Audio condition (mean rank = 14.00) and the VATransition condition (mean rank = 7.00), the test found p = 0.006,— Holm-Bonferroni α = 0.008. This means that both the Visual and the Visual+Audio conditions performed better than the VATransition in terms of score. No other effects were found.

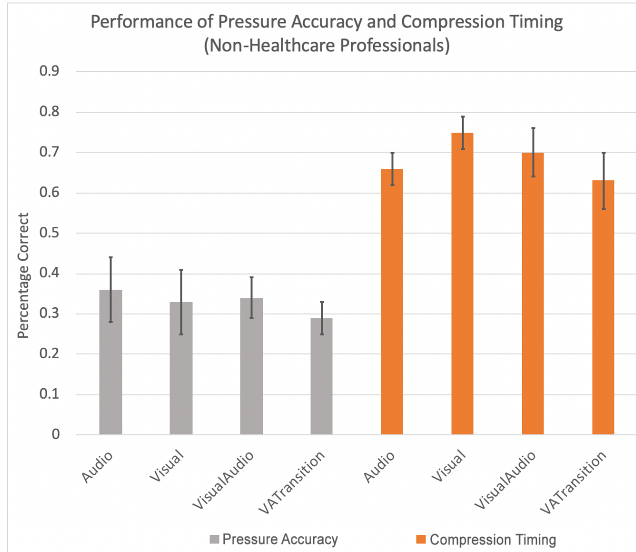


Figure 4: Compression timing and pressure accuracy for non-healthcare professionals

4.1.6 Proper Mask Seal. Indeed, the results of this study present us with the issue of having the proper seal. One of the core characteristics of PPV is having the appropriate mask as well as ensuring a secure and reliable seal between the face of the baby and the mask. For all of the participants in this study, this was their first time exposed to performing PPV on a baby; thus, they may not have the necessary experience to know when there is a leak in their seal. Due to the potential lack of awareness with regards to mask leaks among participants in Study 1, we planned a study with health professionals.

4.2 Study 2 - Healthcare Professionals

Based on the results of Study 1, the Visual only condition and the Audio only conditions were chosen for Study 2. Regarding the Compression Timing, the Visual+Audio condition did not reveal to be significantly better than the Visual only condition while Visual only condition was found to be better than Audio only condition; therefore, we attributed the effect of Visual+Audio to the participants focus on the visual aspect of the condition. Moreover, VATransition was excluded for the same reason, without the visual aspect of the game; our results suggested that participants' performance deteriorated with regards to compression timing.

4.2.1 Participants. Twenty participants (ten females) were health professionals recruited by word of mouth and a poster posted outside of the experimental area. Due to potential emergencies, and the unpredictable nature of hospitals in general, participants came and took part in the study on a walk-in basis, rather than being scheduled. The participants ages ranged from 22-57 years old (M =

39.65, *SD* = 11.25). The participants were nurses, respiratory therapists, and doctors who have been trained and have experience in performing neonatal resuscitation.

4.2.2 Compression Timing. ANOVA was conducted for each component. There was a significant effect found between the Visual (M = 0.71, SD = .15) and Audio (M = 0.48, SD = .16) conditions. The visual condition induced superior performance ($F(1, 19) = 10.84$, $p = .004$).

4.2.3 Pressure Accuracy & Score. No effect was found between the two conditions for pressure accuracy and score. This finding is consistent with the first study.

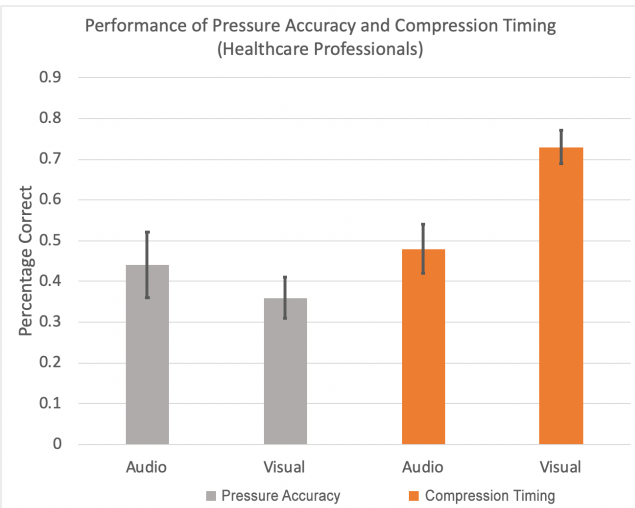


Figure 5: Compression timing and pressure accuracy for healthcare professionals

4.2.4 Missing Data. The frequency of missing data was explored across both the Visual and Audio conditions. A significant effect emerged between the Audio condition of both studies, F (1, 19) = 4.28, p = 0.05. Laypeople failed to respond more often (M = 37.80, SD = 13.31) than experts did (M = 23.10, SD = 16.43). No effect was found between participants in the Visual condition (p = 0.54).

5 DISCUSSION

5.1 Laypeople vs. Healthcare Professionals

Interestingly, no significant effect was found; laypeople and health professionals did not differ in compression timing, pressure accuracy, and score. One interesting outcome, however, comes from the number of missing values. The frequency of missing data (i.e., participants not responding or the response was not entered potentially due to air leak) was explored across both the Visual and Audio conditions. ANOVA was conducted and a significant effect emerged between the Audio condition of both studies, F (1, 19) = 4.28, (p) = 0.05. Laypeople failed to respond more often (M = 37.80, SD = 13.31) than experts did (M = 23.10, SD = 16.43). No effect was found between participants in the Visual condition (p = 0.54).

5.2 Limitations

Mask leakage with this apparatus was a challenging issue. This problem is reflected upon large missing data. The leaks caused participants to be rough with the apparatus and the baby manikin by exerting an unnecessary amount of force to maintain a proper seal. This issue was very prominent across both studies. However, to preserve consistency and reproduce the study for validation, there were no changes to the apparatus between the first study with the laypeople and the second study with the health professionals. This limitation is an important focus for future work with this tool and will be addressed to provide a better training experience.

The qualitative feedback suggest that the Hololens may not be ready for use in training for extended periods. Although the hardware is innovative, participants expressed discomfort with the Hololens (e.g., heavy). With the mask seal being one of the priorities in PPV, future investigations are needed on designs that are able to provide feedback regarding the mask seal in conjunction with the input from the compressions. This implementation would allow users to observe their own masking performance.

5.3 Contribution

This study looks into developing tools to deliver feedback for a specific step of the Neonatal Resuscitation Program training. Furthermore, these tools have the potential to be used frequently for training to maintain an important skill required of the procedure. Currently in North America, refresher training for the procedure is required every two years; however, the lack of effort on skill retention is a concern. Although textbook knowledge is often better retained, studies have shown that skill performance in neonatal resuscitation deteriorates over time [8, 35]. Many researchers have suggested frequent refresher training to improve the performance and the quality of the skills used in this procedure. This research contributes to the ongoing investigation in designing innovative ways to help maintain the performance and quality of skills. By developing a training device that assesses one's PPV performance in real-time, one may be able to use the device independently to maintain the quality of their ventilation in PPV.

5.4 Future Work

The next step in this research is to tackle the design challenges that involve measuring both the seal and the pressure exerted through compressions. Further, the Hololens may not be ready for extended use; thus, moving feedback delivery to another device such as a smartwatch will be fruitful. Investigations regarding skill retention after using the tool is also required through longitudinal studies. If the tool is successful in helping healthcare professionals retain their practical skills in PPV, this tool could also be a catalyst in developing tools for different steps in NRP training. The most intriguing outcome for future work in this area is the potential use of everyday training for skill retention.

5.5 Conclusion

Neonatal resuscitation is a crucial procedure for millions of newborns each year. The process is composed of many intricate steps that require precision and care from the healthcare professionals. One step that requires a considerable amount of practice is positive pressure ventilation. In this research, we studied the effect of using different technologies such as AR devices and a simple gas pressure sensor to help with training by delivering feedback to professionals seeking to practice.

Through gamification of the PPV step, the audio stimulus, visual stimulus, and different combinations of the two stimuli, were compared in an attempt to discover the best form of delivering the feedback. For this research, our main findings come two-fold. First, our results demonstrates that visual feedback performs significantly better than conditions with audio-only feedback in multiple components of the procedure. Second, our findings suggest that between the tasks of maintaining the correct pressure or precisely timed compressions, maintaining the pressure was significantly more difficult to control. The results of both studies conducted show that a visual stimulus is significantly better for compression timing. Both the laypeople and experts exposed to the visual stimulus were able to hit more targets than the participants exposed to the audio stimulus.

The difficulty however, lies within achieving the correct pressure. Both studies show inconsistencies in pressure accuracy as well as cases of unresponsiveness due to a lack of pressure captured by the Phidget pressure sensor. This issue is caused by leaks between the face-mask and the manikin's face. The leaks and the unresponsiveness of the device demonstrate the importance of having a proper seal when one is masking the newborn. The studies potentially suggest that laypeople had a more difficult time maintaining the seal than the experts. A comparison demonstrated that laypeople failed to respond more than the experts did in both the Visual and the Audio condition. However, only the comparisons between the Audio conditions of both groups had a significant effect.

6 ACKNOWLEDGMENTS

We acknowledge support from the Visual and Disease Analytics Program. We would also like to thank Dr. Ganesh Srinivasan and the health professionals at the Heath Sciences Centre in Winnipeg for taking the time to participate in our study.

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