BBAid: Using Smartwatches to Improve Back Blows

Amanda Watson, Gang Zhou

Computer Science Department, College of William and Mary, United States

1. Introduction

In the event of a choking emergency, the flow of oxygen must be restored to the body or hypoxia will begin to occur. Hypoxia is a condition in which the supply of oxygen in the body is insufficient to sustain normal bodily functions. Within a few minutes, this can cause irreparable damage to an individual's brain, vital organs, and nervous system [1]. Within six to eight minutes of the onset of hypoxia, it is likely that organ systems will fail and brain death will occur. In a study of the local choking incidents in the San Diego County Medical Examiner's database, there were 19 incidents that occurred in restaurants in adults over a ten year period. Of the 19 incidents, there was only one attempt by a bystander to perform choking first aid [2]. In the US, choking accounted for 4,800 deaths in 2015 and 5,051 deaths in 2017 making it the fourth leading cause of unintentional injury death according to the National Safety Council's 2015 and 2017 Injury Facts [3][4].

Basic choking first aid training courses are readily available at community centers, hospitals, colleges, some workplaces, and even online. Many first aid training courses include a module on choking first aid and the percentage of trained individuals in US counties varies between zero and fifteen [5]. This training prepares bystanders to react to and provide immediate treatment to a choking victim. When choking first aid is performed, there is a 66% chance the victim will survive [6]. One barrier to a choking victim receiving non-EMS aid is a psychological phenomenon known as the "bystander effect". This effect presents itself when individuals who are in a group environment do not help someone in need of aid because of the belief that someone else in that group is more qualified than they are. In the end, it is likely that no one will intervene as the entire group believes that there is someone more qualified to help [7].

In this chapter, we answer the following research questions:

RQ1: How can we accurately classify back blows with a wearable device?

RQ2: What kind of feedback should we provide to enhance the performance of back blows?

RQ3: How do we combat the bystander effect?

To determine how accurately we can classify back blows with a wearable device we perform a user study in which 109 back blows were performed by ten participants. Then, we extract five features to describe a single back blow from the Z-Axis of smartwatch accelerometer data and feed it into a random forest classifier. From this, we see a classification accuracy of 93.5%.

To understand what kind of feedback we should provide to enhance back blows, we calculated two metrics, developed a smartwatch application called BBAid, and conducted a user study. First, we calculated two metrics: the quality and quantity of back blows. These metrics are then added to the feedback system in the BBAid application. BBAid not only provides instructions on how to perform choking first but also provides feedback to the user on how well they performed back blows. Then we perform a user study in which our participants filled out two questionnaires and performed choking first aid. In this user study, our participants were split into two groups: Group 1 was given a video tutorial and Group 2 was instructed to use the BBAid application.

Email addresses: aawatson@cs.wm.edu (Amanda Watson), gzhou@cs.wm.edu (Gang Zhou)

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To understand if BBAid can help to combat the bystander effect, we asked our participants to answer questions about willingness, comfort, and fear of performing choking first aid on a choking victim. We compared our participant's responses to these questions based on their randomly selected group, previous knowledge, and choking first aid background. We found that all of our participants regardless of group, previous knowledge, or skill were more willing and comfortable with performing choking first aid after receiving training.

When someone is choking, the American Red Cross [8] recommends a series of back blows and abdominal thrusts. To the best of our knowledge, to date, a system for the back blow portion of choking first aid scenarios that provides instructions and feedback has not been developed. Watson and Zhou[9] developed an application for the abdominal thrust portion. Zoll Medical Corporation [10] and Dechoker LLC [11] developed devices that could be used in choking first aid scenarios. Zoll Medical Corporation solely focuses on the abdominal thrusts and does not consider back blows. Dechoker LLC takes a new approach to choking first aid that does not involve abdominal thrusts or back blows. CPR feedback on smartwatches and other devices has been developed and is being deployed into training facilities [12][13][14]. Frequently, choking first aid is taught in CPR first aid courses which gives us the opportunity to leverage the systems already in place in training facilities. First aid skill retention is a known problem [15][16][17] and it has also been shown that choking first aid skills decline more rapidly than others [18]. We address this decline in skills and knowledge by providing feedback and instructions at the time choking first aid would need to be performed.

Our contributions are summarized as follows:

- We are the first to extract features from smartwatch accelerometer data and use it to accurately classify back blows. We selected five features to describe a single back blow. We feed these five features into a random forest classifier and see a 93.5% accuracy.
- We are the first to provide insightful feedback to enhance back blow performance. We calculate two metrics: quality and quantity of back blows that are used to provide feedback. In our final user study, all of our participants experienced an increase in performance while using BBAid.
- We propose and develop the first smartwatch application that incorporates our features, classifier, and feedback to combat the bystander effect. All of our participants saw an increase in their willingness to perform choking first aid when using the given choking first aid instructions.

The remainder of this chapter is structured as follows. First, we will discuss our related work and preliminary study with a background on choking first aid. Second, we will discuss and evaluate our system design and BBAid. Then we will describe our Post-User Study and our results from it. Finally, we will wrap up with a discussion of future work and summarize with a conclusion.

2. Related Work

Our Related Work section is broken into three parts. First, we discuss first aid skill retention. Second, we examine current choking first aid devices. Third, we consider the impact that CPR training on smart devices has on our research.

2.1. First Aid Skill Retention

First aid skill retention is a known problem as many necessary skills are often forgotten shortly after training [15][16][17]. Anderson et al [18] determined how rapidly the trained skills and knowledge decayed. They conducted a large study in which they tested the choking first aid skills of first responders in an industrial setting. They found that the higher level an individual has been trained at, the less their knowledge and skills decay over time. They also found that during this study choking skills were performed poorly regardless of how long it had been since the participant was trained. To combat the skill and knowledge decay, they recommend shortening the time between training sessions. It is possible that our system can help with skill and knowledge decay. When needed in an emergency situation, BBAid can refresh user knowledge and help improve the quality of the skill being performed.

From this study [19], we see that bystander first aid performance can be greatly improved when audio instructions are given through a personal digital assistant (PDA). Their study focused on trauma victims with severe bleeding or those who needed cardiopulmonary resuscitation (CPR) first aid. They divided participants into two groups: the first received audio and video instructions via the PDA and the second acted as a control group by using only their current knowledge. Their results show that the first group performed significantly better than the second when giving emergency care. Similarly, in this paper, we provide emergency care instruction but we take it a step further and provide live feedback to the user on their performance of that care as well. Deploying our application on a smartwatch instead of a handheld mobile device also allows for hands-free use by the user.

2.2. *Choking First Aid Devices*

Researchers have developed devices to aid in the performance of choking first aid. The first of these devices is outlined in a patent filed by Totman at Zoll Medical Corporation [10]. This patent describes a method to measure abdominal thrusts. In this patent, a handheld device that uses accelerometers to determine the appropriate depth and speed of the abdominal thrusts is described. This device targets first aid training, but they do not have an extensive evaluation on how this device could improve user learning and performance. In contrast, our system provides in-situ instruction and real-time feedback on the quality of each set of abdominal thrusts.

The Dechoker [11] is a commercially available FDA Class I medical device. To use the device, the operator inserts a plastic tube inside the mouth and places the mask on the face. When tested on cadavers, this device did not cause injuries but it also did not remove the foreign object in all cases. It is noted that this device may damage the soft tissues of the mouth, lodge the foreign object deeper in the airway, cause mucosal injury and or negative pressure pulmonary edema [20]. While this device could be helpful in choking emergencies, there is not enough published data to understand the risks.

2.3. *CPR on Smart Devices*

Smart devices make great tools for providing instructions and feedback for first aid because they are readily available and easy to use. Choking first aid is commonly taught in the same training sessions as CPR. CPR instruction and feedback applications have been developed and are even being used in training facilities [12][13][14].

Watson and Zhou [9] developed a smartwatch application that provided real-time feedback on the abdominal thrust portion of choking first aid. Their application improved the performance of abdominal thrust by providing feedback on the number and acceleration of thrusts. Their application was evaluated on abdominal thrusts done on a CPR manikin. Gruernerbl et al and Ahn et al [13] [14] developed applications for a smartwatch that provided real-time feedback for CPR chest compressions. Their applications were meant to enhance the performance of CPR chest compressions by measuring the frequency and depth of the compressions. They tested their applications on chest compressions performed on a CPR manikin. They demonstrated that their application not only improves the user's performance of CPR, but it also increases user's potential for performing it. Gruernerbl et al showed that a smartwatch feedback system provided a significant performance improvement on CPR techniques. Ahn et al showed that CPR related feedback via a smartwatch could provide assistance with respect to the ideal range of chest compression depth, and this can easily be applied to patients with out-of-hospital arrest by rescuers who wear smartwatches. In our work, we address a different first aid maneuver: back blows. Similarly, we show that our smartwatch feedback application improves the technique and likelihood that the user will perform choking first aid.

Elliot et al [12] developed a smartphone application to assist with training and knowledge retention for CPR. They record the depth and frequency of chest compressions. Their application can be used for training scenarios at or away from the training location. This combats the decay of knowledge and skills that occurs after training because a user's skills may be monitored remotely. Since smartphones are still more prevalent that smartwatches this makes feedback on CPR techniques available to more individuals.

3. Preliminary Study

We want to evaluate whether a smartwatch application that provides feedback will improve choking first aid. To do this, we performed a user study where we asked our participants to wear a smartwatch and to perform choking first aid on a CPR training manikin. Based on the above, we formulated the following study questions:

SQ1: What is the user awareness of proper choking first aid?

SQ2: How does user awareness improve with the addition of live feedback?

3.1. Study Setup

First, we will provide a background on choking first aid. In this chapter, we follow the method recommended by the American Red Cross. We continue by describing our user study in terms of the equipment used, the parameters of the study, and the demographics of our participants.

Choking First Aid Background: The American Red Cross recommends the following quoted treatment for choking victims [8]:

- "After checking the scene and the victim, have someone call 911 and get consent to perform first aid."
- "Bend the victim forward at the waist and give five back blows between the shoulder blades with the heel of one hand."
- "Place a fist with the thumb side against the middle of the victim's abdomen, just above the navel. Cover your fist with your other hand. Give five quick, upward abdominal thrusts."
- "Continue sets of five back blows and five abdominal thrusts until the object is forced out, the victim can cough forcefully, breathe, or the person becomes unconscious."

Equipment: The smartwatch application used to collect accelerometer data was implemented on a Motorola 360 smartwatch [21]. This application was connected to a Google Pixel smartphone [22] where the data files were stored. We tested a preliminary mechanism for choking first aid where we observed the participants' response to real-time feedback during abdominal thrusts [9].To provide feedback, we used a threshold based method on smartwatch accelerometer data to detect participant thrust strength. We provide no feedback for back blows.

Figure 1: The "Annie" CPR training manikin used in our study.

Parameters: Our study began with a simple questionnaire in which we gauge each participant's knowledge, willingness to perform choking first aid, and their familiarity with smartwatches. Then we asked each user to wear a Motorola 360 smartwatch and perform choking first aid on a CPR manikin [23], shown in Figure 1. During this part of the study, we randomly split the participants into two groups. Group 1 was shown an educational video from the American Red Cross [24]. Group 2 was given a smartwatch application that provided choking first aid instructions and included our preliminary mechanism for real-time feedback on abdominal thrusts. Following this, we gave each participant a follow-up questionnaire to determine if their willingness to perform choking first aid and comfort with a smartwatch had changed as well as a free response question for any additional feedback they had. Ground truth for this study is collected by having a researcher who is observing the study log the time at which each back blow started. Ground truth labels were back blow and not back blow. In this study, motions that were classified as not back blows include abdominal thrusts, picking up and putting do the manikin, repositioning the manikin, any actions or adjustments made between back blows or abdominal thrusts.

Demographics: We recruited the participants in our study from the College of William and Mary and the surrounding area. In total, we had ten participants. Of our participants, eight were female and two were male. In terms of age, on average, the participants were 35.4 with a standard deviation of 14.6. Prior to this study, only four participants had some form of first aid training.

3.2. Study Results

We asked our participants two questions regarding smartwatches. The first question was "On a scale of 1-5, how familiar are you with smartwatches?". The second question was "Did the smartwatch irritate you? Yes or No. If yes, why?". We asked these questions to determine how familiar our users were with a smartwatch and if it could potentially irritate them when performing choking first aid maneuvers. On a scale of 1-5, our participants averaged a 1.8 in terms of smartwatch familiarity with a standard deviation of 1.3. Since our subjects are not highly familiar with smartwatches, it follows that if they do well with the application it should be easy for new adopters to use. Only one of our ten participants found the smartwatch to be irritating stating that "It was a bit big". From this, we conclude that a smartwatch will make a good tool for choking first aid as it is not irritating to users.

We compare our participants' willingness to perform choking first aid before and after performing choking first aid. Before beginning, we asked our participants to rate their willingness to perform on a scale of one to five. We repeated this question after they had performed choking first aid and these results are shown in Figure 2. Participants one through five were shown the Red Cross video and participants six through ten were given the smartwatch app. From this figure, we clearly see that those who received the application had a greater increase in willingness to perform choking first aid. On average the participants who were shown the video had a willingness increase of 2.8 while those who were given the application had a feedback increase of 4.2.

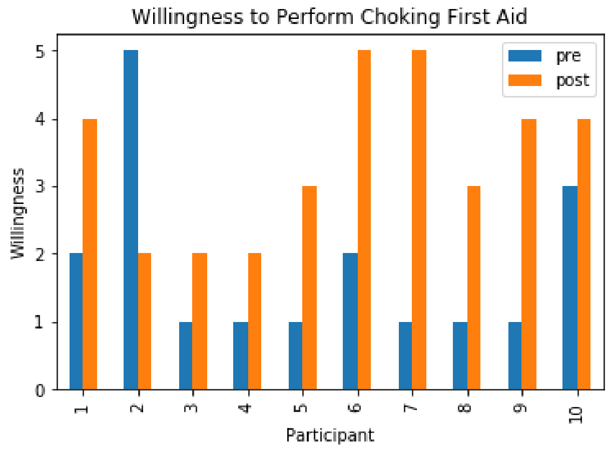


Figure 2: Willingness to perform choking first aid.

Part of our study included a short survey in which the user could provide open-ended answers to questions. Of our ten participants, four mentioned back blows. More specifically, their comments were as follows:

- "The instructions helped. I had never heard of back blows."
- "Please add feedback on the back blows as well."
- "You should also tell me when I am doing back blows correctly."
- "I only knew of the Heimlich maneuver before... thanks for informing me about back blows."

These comments fall into two categories: a lack of knowledge about back blows and request for a feedback system similar to the one used for abdominal thrusts. The existence and combination of these two deficiencies demonstrates that the users feel the need for live feedback to help improve their performance.

We also look to see whether our participants' performance of abdominal thrusts improved with the addition of feedback. All five participants saw improvements in the performance of abdominal thrusts. Feedback for back blows was not given in this study. Following our hypothesis that the addition of feedback improves performance, only one participant improved in the performance of back blows. The common issue in the performance of abdominal thrusts and back blows is that the participant does not provide enough force when performing the maneuvers. We saw that providing feedback helps the participant to increase the force provided for abdominal thrusts. It follows that this will also be the case for back blows.

4. System Design

In this section, we describe the design of BBAid, an Android smartwatch application that assists the user in their performance of choking first aid by providing them with instructions and feedback on their performance. We begin by describing the features used, then we explain how we use those features to detect a back blow event. Finally, we show how we calculate the metrics we use to provide feedback on the user's performance of back blows.

4.1. System Architecture

Here, we describe the pipeline for the classification and quality metric calculation of the back blow portion of choking first aid. First, we must acquire accelerometer data from a smartwatch accelerometer. Next, we extract 5 features that will be used in our classifier to classify an event as either a Back Blow (BB) or Not Back Blow (NBB). Finally, we define and calculate two metrics that are the basis for the feedback provided to the user.

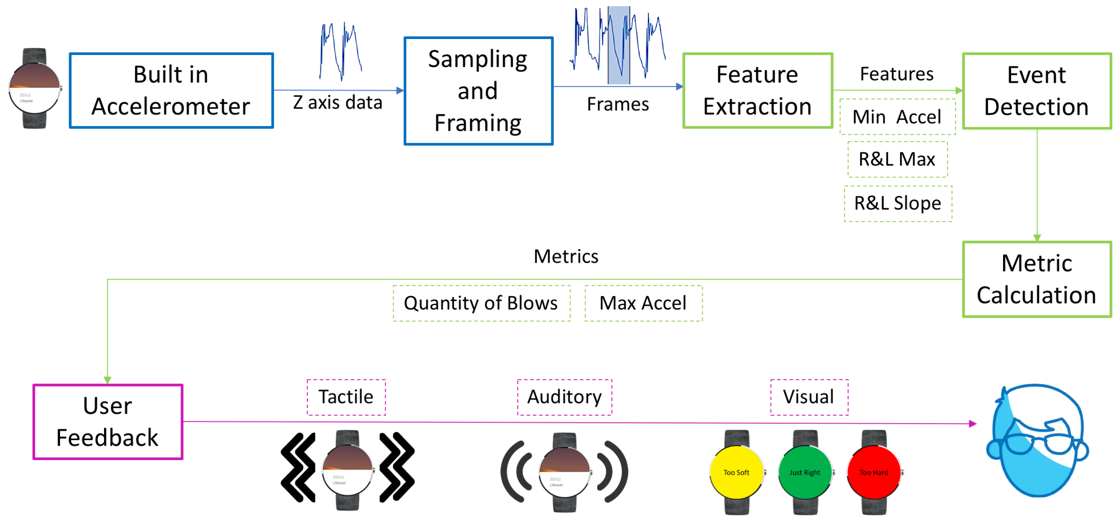


Figure 3: System Architecture of BBAid.

4.2. *Feature Extraction*

In Figure 4 we show an example of a single back blow event. As seen in the figure, back blows have a very distinct shape due to the nature of the change in direction of the acceleration. To classify back blows, we use accelerometer data in the Z-axis. If the Z-axis acceleration exceeded a threshold, $\mathcal{E}_{threshold}$, the next local minimum is sought. $\mathcal{E}_{threshold}$ is defined as the maximum of the acceleration peaks of the ground truth data collected in the Preliminary Study. The value of $\mathcal{E}_{threshold}$ is 3.083. We then draw a window of size .85 seconds equally spaced around the minimum. The size of the window is determined by the size of the longest back blow from the training data collected in the Preliminary Study with an additional 50% of that time added. In Figure 4 we label the features we calculate as follows:

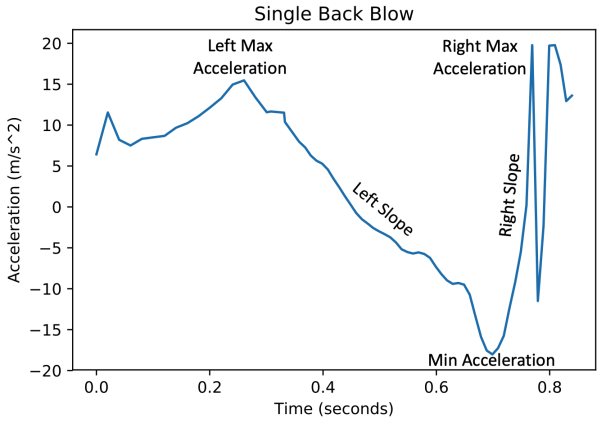


Figure 4: This is a visual representation of a single window of Z axis accelerometer data that contains a back blow. The five extracted features are labeled.

First, we define:

$$arg(x_i) \triangleq i \quad (1)$$

Then, on each sliding window, $Input = [x_1...x_n]$, we calculate 5 features:

$$MinAccel = \min_i(x_i) \quad (2)$$

$$MaxLeft = \min_{x_i \in [x_1, MinAccel]}(-x_i) \quad (3)$$

$$MaxRight = \min_{x_i \in (MinAccel, x_n]}(-x_i) \quad (4)$$

$$SlopeLeft = \frac{MinAccel + MaxLeft}{arg(MinAccel) - arg(MaxLeft)} \quad (5)$$

$$SlopeRight = \frac{MinAccel + MaxRight}{arg(MaxRight) - arg(MinAccel)} \quad (6)$$

4.3. Event Detection

To detect each back blow event we fed our five features that are described above into several classifiers that were successfully used in other sensing-based activity classification research [25][26][27][28]. These classifiers were random tree, random forest, SMO (Sequential minimal optimization), KNN (K-Nearest Neighbor), and Logistic Regression. To test these classifiers, we leveraged the Weka Data Mining Software provided by the University of Waikatao [29]. We evaluated these classifiers on three metrics: precision, recall, and the effort it takes to run the classifier and the results of our evaluation are shown in Table 1. From these results, three of the five classifiers outperformed the rest in terms of precision and recall: Random Forest, SMO, and KNN. These classifier exhibit high precision and high recall meaning that these algorithms return a high number of correctly classified back blow instances. Since we had high precision and recall for three algorithms, we also evaluated them on the amount of effort it takes to train and use each algorithm. This is shown in the effort column in figure 1. We chose random forest for use in BBAid because it exhibits the highest precision and recall while being in the low effort category. We evaluated our classifiers using the Preliminary Study data. In this data set, we have a total of 109 back blow events.

Classifier	Precision	Recall	Effort
Random Forest	93.5	93.5	low
Random Tree	91.4	91.4	low
SMO	93.7	93.5	mid
K - Nearest Neighbor	93.5	93.5	high
Logistic	90.9	90.9	low

Table 1: Evaluation of multiple classifiers on our data set.

4.4. Metric Calculation

We calculate two metrics to gauge user performance of back blows: quantity of back blows and quality of back blows. First, we determine the quality of back blows by comparing the minimum acceleration of each user's back blows to the average minimum acceleration of our expert data. Second, we calculate the number of back blows by keeping a running total of the number of back blows performed.

When performing back blows it is important for the user to provide enough acceleration to effectively dislodge the object. Due to the lack of availability of a recommended acceleration for an individual back blow, we asked five experts to perform back blows on a provided Annie [15] CPR manikin while we recorded their accelerometer data. The five experts consisted of three CPR certified lifeguards and two emergency medical technicians (EMT). We instructed each expert to perform ten back blows for a total of fifty back blows. The mean minimum acceleration was -14.63 with a standard deviation of 2.591. There were three outliers in the data set that were removed. The minimum acceleration was -17.02 and the max acceleration was -12.32. We compare the expert data to the data collected in the preliminary user study and show this in a histogram in figure 5. In this figure, it is easy to see the difference between the expert and participant data. The expert data falls mostly between -12 and -18 while the participant data is further spread out from three to -20.

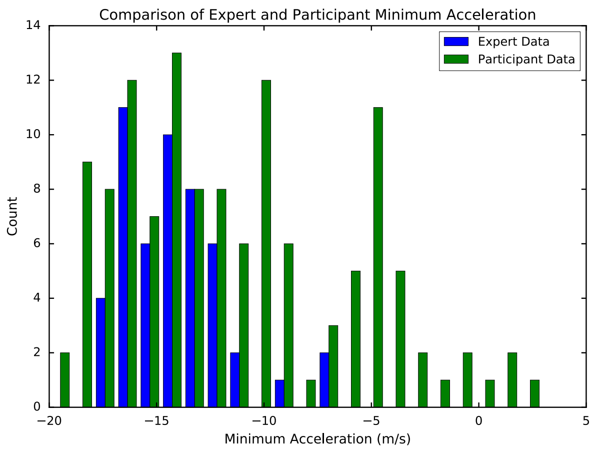


Figure 5: Histogram comparing the expert and participant minimum acceleration data.

5. BBAid Application

BBAid provides two functions. First, it provides simple, clear, and concise easy instructions for choking first aid. Second, it provides feedback to the user on their performance of the back blows. BBAid is implemented on Android 8.0 Oreo. The smartphone application is approximately 4.3 MB and the smartwatch application is about 3.5 MB. BBAid samples the accelerometer and gyroscope at a rate of 5 Hz. The display, data processing, and data logging are implemented in their own threads so that feedback is provided to the user in real-time.

(a) (b) (c) (d)

Figure 6: Instructional screens from BBAid.

5.1. Instructions

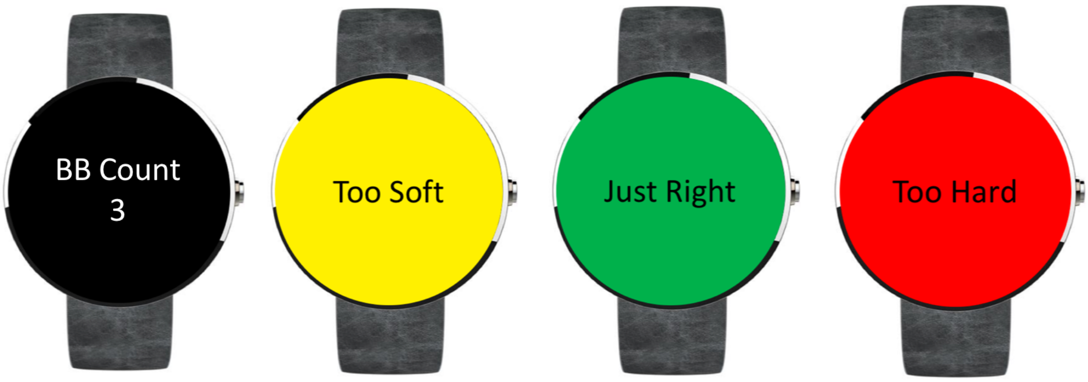
Instructions for BBAid must be clear and concise because of the limited space available on smartwatch screens. Our instructions must also be simple and easy to understand for the user. Because of this, we designed our smartwatch screens to show both a title and description. The title is an overall summary of the current screen's instruction. The description is a more detailed explanation. When a user first opens BBAid, they are greeted with a welcome screen shown in Figure 6a. Following this, the application gives instructions based on the Red Cross recommended choking first aid procedure [8]. To navigate through the pages, the user swipes left as they are finished with each screen to proceed.

The first step in the Red Cross procedure is to alert the EMS services. The first instructional screen in BBAid, shown in Figure 6b, titled "Call 9-1-1" reminds the user to "Send someone to call 9-1-1". Next, it is important to begin first aid maneuvers. The Red Cross recommends beginning with 5 back blows, following with 5 abdominal thrusts, and then repeating that process until the foreign object is either expelled or the person becomes unconscious. Illustrating this, the next two screens shown in Figure 6c and Figure 6d give an overview of the maneuver to be performed along with a more detailed description. For back blows, BBAid displays "5 Back Blows" with a description of "Lean person forward and give 5 back blows with the heel of your hand". For abdominal thrusts, it displayed "5 Ab Thrusts" with a description of "Place the thumb side of your fist just above the navel. Grab your fist with your other hand. Give 5 quick, upward abdominal thrusts". Altogether these instructional screens give the user reminders for the correct way to perform choking first aid as a whole.

5.2. Feedback

BBAid utilizes three types of feedback that can be given through a smartwatch: tactile, auditory, and visual. When the user swipes left to move on from the back blow instructional screen, they are shown the first feedback screen. This screen is shown in Figure 7a and counts the number of back blows that the user has performed. For each logged back blow, the smartwatch provides tactile feedback in the form of a 150 millisecond vibration and a beep sound on smartwatch devices with a speaker. Once the user has completed and logged five back blows, BBAid averages the minimum acceleration of the five back blows and show the user one of three force feedback screens.

We break the feedback into three options: too soft, too hard, and just right. We based the colors used for each screen on the stoplight coding method [30]. The stoplight coding method has been shown to be effective at promoting understanding of the meaning of the info rmation presented [31][32][33]. The stoplight coding method is a method that maps red to stop, yellow to caution, and green to go. We use this method in a similar mapping. When the back blow average is too soft we provide the user with the yellow screen shown in Figure 7b. When the back blow average



(a) (b) (c) (d)

Figure 7: Screens that provide feedback for back blows in BBAid.

is too hard we provide the user with the red screen shown in Figure 7d. When the back blow average is just right we provide the user with a green screen shown in Figure 7c.

We use the data collected from the experts to set the thresholds for each option. In this case, we removed the three outliers from the data set. This leaves us with a maximum of -12.329 and a minimum of -17.026. We used these values as the max and minimum for our just right option. All values lesser than -17.026 will be classified as too hard and all values greater than -12.329 will be classified as too soft.

6. User Study

In this section, we evaluate BBAid and its effects on our participants' performance of back blows and their willingness to perform choking first aid. To do this we performed a user study in which we asked our participants to answer two questionnaires and perform choking first aid on a manikin. Given this, we formulate the following study questions:

SQ1: How does real-time feedback on back blows improve the user's performance and technique?

SQ2: Can our application combat the bystander effect in relation to choking first aid?

6.1. Study Setup

In the study setup, we first give a background of choking first aid. Then, we describe the equipment we use in this user study. Next, we will discuss the parameters of the study. Finally, we will discuss the demographics of our participants.

Choking First Aid Background: We followed the same recommended treatment in this user study as we followed in the Preliminary Study. This is the American Red Cross recommended treatment for victims of choking [8]. We quote the method as follows:

- "After checking the scene and the victim, have someone call 911 and get consent to perform first aid."
- "Bend the victim forward at the waist and give five back blows between the shoulder blades with the heel of one hand."
- "Place a fist with the thumb side against the middle of the victim's abdomen, just above the navel. Cover your fist with your other hand. Give five quick, upward abdominal thrusts."
- "Continue sets of five back blows and five abdominal thrusts until the object is forced out, the victim can cough forcefully, breathe, or the person becomes unconscious."

Equipment: During our study, participants wore an LG Urbane [34] Android smartwatch on the wrist of the hand that they would use to perform back blows. We collected accelerometer and gyroscope data from the smartwatch and sent these measurements wirelessly over Bluetooth to a Google Pixel Android Smartphone [22]. Our study also required the user to perform choking first aid procedures on a first aid manikin. While there are many first aid manikins to choose from, we selected the "Annie" CPR manikin [23] as it is readily available at most first aid training facilities.

Pre-Study Questionnaire

1. Have you had choking first aid and/or Heimlich maneuver training?
   Yes or No
   If yes, why?
2. On a scale of 1-5, how comfortable are you performing the choking first aid?
   1 2 3 4 5
3. Is the topic of the study (choking first aid) relevant for you personally?
   Yes or No
   Why?
4. On a scale of 1-5, how willing are you to perform choking fi
   1 2 3 4 5
5. On a scale of 1-5, how familiar are you with smartwatches?
   1 2 3 4 5
6. Which is your dominant hand?
   Right Left Ambidextrous

(a) Questions filled out before performing choking first aid.

Post-Study Questionnaire

1. Did the smartwatch irritate you?
   Yes or No
   If yes, why?
2. On a scale of 1-5, how willing are you to perform choking f after watching the Red Cross Video Tutorial?
   1 2 3 4 5
3. Did you feel that you performed choking first aid better aft watching the Red Cross Tutorial Video?
   Yes or No
   why?
4. Did watching the Red Cross video tutorial reduce your fear injuring the person you are performing choking first aid on
   Yes or No
   why?
5. Any other comments?

(b) Questions filled out after performing choking first aid and viewing the training video.

Post-Study Questionnaire

1. Did the smartwatch irritate you?
   Yes or No
   If yes, why?
2. On a scale of 1-5, how willing are you to perform choking first aid using a smartwatch with our app?
   1 2 3 4 5
3. Did you feel that you performed choking first aid better with the smartwatch?
   Yes or No
   why?
4. Would using the smartwatch with our app reduce your fear of injuring the person you are performing choking first aid on?
   Yes or No
   why?
5. If you had a smartwatch, would you install our app?
   Yes or No
   why?
6. Any other comments?

(c) Questions filled out after performing choking first aid while using BBAid.

Figure 8: Questionnaires filled out by participants in our user studies.

Parameters: We conducted our study in a lab setting. When our participants entered the lab, they were asked to fill out some demographical information and a Pre-Study Questionnaire. The questionnaire is shown in Figure 8a. With this questionnaire, we attempt to gauge each participant's base knowledge of choking first aid and their willingness to perform it. Following this, we began the portion of the user study in which the participants performed choking first aid. Each participant was given two scenarios. In Scenario 1, we asked the participant to use any previous knowledge to perform choking first aid on the manikin. For Scenario 2, we randomly divided our participants into two groups. Group 1 served as our control group and was shown this training video [24] provided by the American Red Cross. Group 2 was instructed to open the BBAid application on the smartwatch and follow the instructions provided in the app. Finally, all participants were asked to fill out a Post-Study Questionnaire to gauge how their willingness to and fear of performing choking first aid changed. Group 1 was asked to fill out the questionnaire shown in Figure 8b and Group 2 was asked to fill out the questionnaire shown in Figure 8c.

Demographics: We recruited our study participants from the College of William and Mary and the surrounding areas. Our user study consisted of 16 participants: 12 male and 4 female. On average the participants were 28 years old with a standard deviation of 4.6 years. Overall our participants had an average BMI of 25.53 and a standard deviation of 4.5. All participants were right-handed. Prior to this study, only two participants had first aid training.

6.2. Study Results

6.2.1. Back Blow Classification

In this study, there were 80 possible real-time back blow classifications for BBAid to make. Of those 80 possible classifications, BBAid classified 75 in real-time achieving a classification accuracy of 93.75%. Of the five that were not correctly classified, three were recognized after a few seconds of lag time and two were not recognized. Post analysis of the two unclassified back blow events revealed that these back blows did not reach the maximum acceleration required by the application.

6.2.2. User Performance

We compared our two groups in terms of three metrics from the post-training scenario: simulating calling 9-1-1, manikin position, and max acceleration on their abdominal thrusts. We show the correct manikin position in Figure 9. For Group 1, we saw that two individuals simulated calling 9-1-1, six participants held the manikin horizontally, and only one made it to the recommended back blow acceleration. For Group 2, we saw that eight individuals simulated calling 9-1-1, eight participants held the manikin horizontally, and only six made it to the recommended back blow acceleration. These results are shown in the Scenario 2 column of Table 2.

	Scenario 1			Scenario 2		
Group #	9-1-1	MP	Max Accel	9-1-1	MP	Max Accel
1	3	1	1	2	6	1
2	1	1	0	8	8	6

Table 2: Performance of each group in Scenario 1 and Scenario 2. MP is short for manikin position.

We also compared each group's improvement between the first and second scenario. In Group 1, we saw that one less participant simulated calling 9-1-1, five additional participants positioned the manikin correctly and no additional participants were within the recommended maximum acceleration range after video training. In Group 2, we saw that seven additional participants simulated calling 9-1-1, seven additional participants positioned the manikin correctly and six additional participants were in the recommended maximum acceleration range when using BBAid. These results are shown in Table 2.

In our Post-Study Questionnaires, we asked each of our participants if they believed they had performed choking first aid better with either the tutorial video or BBAid and why. This was asked in question three of both Post-Study Questionnaires shown in Figures 8b and 8c. In Group 1, seven participants believed that they performed choking first aid better. In Group 2, all eight participants believed that they performed choking first aid better. We also opened up this question for a free response as to why they felt they had performed better or worse. Overall, Group 1's responses were centered around instructions and reminders of what they knew before. More specifically:

- "Because there were details I had forgotten from when I was trained."
- "Clear and concise directions on what to do."
- "I now know the correct way to perform the back blows and abdominal thrusts."

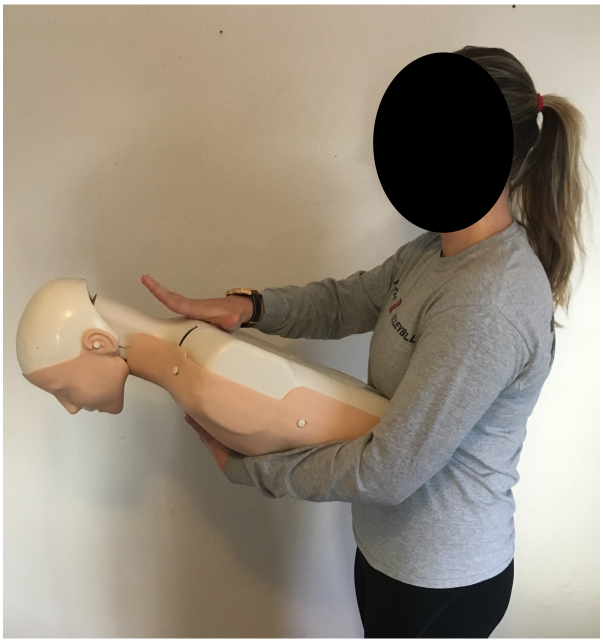


Figure 9: Correct manikin position when performing choking first aid.

In summary, Group 2's responses reflect the feedback they received for back blows. More specifically:

- "The feedback helped. I was able to adjust to it."
- "The feedback helped me get to a green screen. I feel like I could save someone."
- "Easy to follow instructions. Feedback is a great addition"

6.2.3. User Knowledge

In our study, two participants had prior first aid training. The first was trained and certified as a basic level emergency medical technician (EMT-B) from 2009 through 2012. The second was certified as a lifeguard in 2007 and in American Red Cross first aid in 2012. Both of these participants were randomly assigned to Group 1. The EMT-B trained participant was the only participant in Group 1 to make it to the recommended maximum acceleration. This participant correctly performed all of the metrics we measured except they did not position the manikin correctly in the first scenario. The American Red Cross first aid trained participant did simulate calling 9-1-1 pre and post-training but they did not reach the recommended max acceleration in either scenario and did not position the dummy correctly in the first. From this, we see that previous training can improve performance in a choking first aid scenario but even those with training can use a reminder of the correct choking first aid procedure.

Of our sixteen participants, four did not attempt to perform first aid on the manikin in Scenario 1. These participants did not take the step to simulate calling 9-1-1 or even approach the manikin because they were not comfortable and lacked a basic knowledge of first aid. When randomly divided into groups, three of these were in Group 1 and one was in Group 2. Of those in Group 1, after the training video, none of the three simulated calling 9-1-1, two positioned the manikin correctly, and none got to the recommend acceleration. The participant in Group 2 simulated calling 9-1-1, positioned the manikin correctly, and made it to the recommended acceleration. This suggests that since BBAid provides instructions in real-time there is less chance for a step to be forgotten. Since BBAid provides feedback to the user as they perform back blows, our participants without any prior training were able to perform at the recommended maximum acceleration. This suggests that real-time feedback can help even those that have not been trained for an emergency situation.

6.2.4. User Feedback

To combat the bystander effect in respect to choking first aid, we gauge how our users felt about performing back blows prior to and after training. We do this with questions numbers two and four in the Pre-Study Questionnaire 8a and question numbers two and four in the Post-Study Questionnaires 8b and 8c. First, we will address user willingness, followed by their comfort and fear level when performing choking first aid.

Comfort and Willingness: We asked our participants how willing they were to perform choking first aid before and after their training. We show the results per participant of these questions in Figure 10. From this figure, we see that regardless of their group, most individuals ranked highly on willingness and were more willing to perform choking first aid after being trained. Since both groups receive instructions on how to perform choking first aid, we conclude that information is the key to making our participants more willing to perform choking first aid. abovecaptionskip -11pt

We also asked how comfortable our participants were if they had to perform choking first aid prior to their training. Overall, our participants had an average comfort level of 2.2 out of 5. We had two participants with prior first aid training. Their comfort levels were a four and five out of five. The average comfort level for our untrained participants was 1.86 out of 5. Here we saw that our participants with training were much more comfortable with performing choking first aid than those who did not.

Fear: We survey our participants to see if they were fearful of injuring a choking victim after being trained by the video or the application. Of our sixteen participants, fourteen responded that they were not fearful. Their free response is as follows:

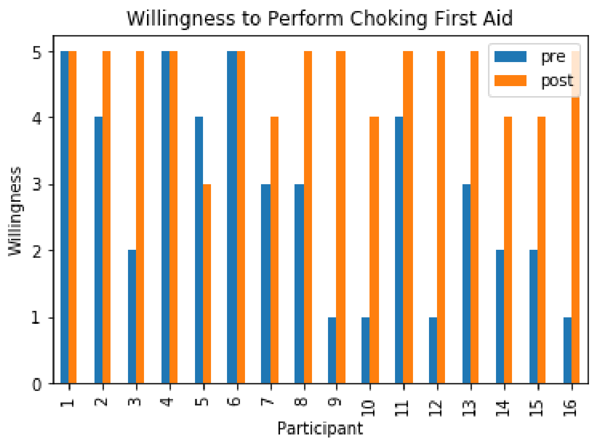


Figure 10: Willingness to perform choking first aid.

- “BBAid gave me more confidence in what I was doing because I know I am applying the right amount of force.”
- “I had no idea what I was doing but with your app I got to the point where I was doing it right .”
- “By watching the video I know the right way to perform the choking first aid. Thus, I am not afraid about it.”

The two participants that were fearful of injuring a choking victim had these responses to our free response question:

- “I had prior training and the video didn’t teach me anything I didn’t know.”
- “Isn’t it possible to break their ribs?”

7. Discussion and Future Work

7.1. Abdominal Thrusts

According to the American Red Cross recommended choking first aid procedure [8], there are two maneuvers to be performed on a choking victim: back blows and abdominal thrusts. Abdominal thrusts are described as: “Place a fist with the thumb side against the middle of the victim’s abdomen, just above the navel. Cover your fist with your other hand. Give five quick, upward abdominal thrusts” [8]. In this chapter, we only address back blows but to provide a complete choking first aid feedback application abdominal thrusts must also be addressed. Providing feedback on abdominal thrusts presents their own challenges as the force of impact, angle of thrust, and number of thrusts should be taken into account.

7.2. First Aid Training

Our application was mainly tested on individuals who had not had formal training in first aid. To see what effect BBAid would have on previously trained individuals it is necessary to complete a study where they are the targeted participants. During this study, it would be important to note if they were current on their certification, how long it had been since their training, and their current knowledge level. In our study, we saw that previously trained individuals did not perform every step recommended by the American Red Cross, for example calling 9-1-1. Because of this, it is important to see how just those who train perform with the aid of the BBAid application.

8. Conclusion

In this paper, we present BBAid: a novel Android smartwatch application for the improvement of choking first aid. Our application classifies and provides real-time feedback on the back blow portion of choking first aid using the data from a smartwatch accelerometer. Our application increases the user’s performance of the back blows by providing instructions and feedback. BBAid combats the bystander effect by increasing user comfort and willingness to perform choking first aid. It also gives the user more confidence by decreasing their fear of injuring a choking victim. BBAid achieves a classification accuracy of 93.75% for back blows in real-time. Following the classification, BBAid analyzes the back blow and provides feedback on its quality. Because of this feedback, our participants are able to perform back blows within the recommended range 75% of the time.

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