Evaluation of Input Modes for BSAFE, A Women's Wearable Safety Device

Yassaman Rezvani
Carleton University
Ottawa, Canada
yassaman.rezvani@carleton.ca

Siju M. Philip
School of Information Technology
Carleton University
siju.philip@carleton.ca

Chanpreet Singh
School of Information Technology
Carleton University
chanpreet.singh@carleton.ca

ABSTRACT

This paper is an empirical study to find the women's preferred mode of interaction, Press or Tap, with a wearable safety device. The goal of our study was to answer the following research question, "What would be the preferred mode of input that women use to interact with a wearable safety device?". Therefore, we designed and developed a wearable prototype, BSAFE, in form of a bracelet with a button and a touch surface to be used by participants in the study. Based on the findings from the user study, women's preferred mode of input is Press. The results suggest that the input mode Tap is more prone to error than the input mode Press. Through the open-ended questions and interviews, we found that most women prefer to wear their safety device on their wrist. Based on our results and findings, the future researchers could integrate the preferred interaction method into their device.

Author Keywords

Wearable Device; Women's Safety; Input Modes.

ACM Classification Keywords

H.5.m.

INTRODUCTION

Safety for women is a growing concern. According to the department of Justice Canada, women are sexually assaulted at a higher rate (37 incidents per 1,000 women) than men (5 per 1,000 men) [1]. Given the technological advances in the 21st century, a question that comes to mind is how could these advancements help to protect women against sexual or physical assault [3]?

To help women in emergency situations, researchers have designed and developed a number of safety devices. Most of these devices use mobile applications (apps) [5]. Smartphone technology and its apps have enabled users to send their current location and urgently call friends, family, and the police, and record the crime scene in time of an emergency [3]. These devices require the user's full attention and are not easily accessible in an emergency situation. Some of these safety devices are unreliable since they depend on the internet connection. A safety device that can be used in time of an emergency needs to be discreet, reliable, easily accessible and easy to use [5]. A wearable safety device that is useable, useful, and efficient and specifically designed for women could be one solution [5]. In case of an emergency, wearables are easier and faster to access than mobile phones and because of their size and on-body placement, they are discreet and less noticeable by the attacker. Wearables are always on and interaction with wearables do not demand the wearer's full attention, which results in less user distraction [17]. The safety applications in these wearables can make a call and send notifications to the police and the user's family when invoked [3].

The term usability has been defined as "the extent to which a product can be used by specified users to achieve specific goals with effectiveness, efficiency and satisfaction in a specified context of use" [14]. In academia, researchers have studied reliability and accuracy of wearable devices, however, few studies related to usability evaluation of safety wearables have been done to date [15]. We looked at different literature in regards to safety mobile applications and wearable devices and found only one paper that had evaluated their prototype through a user study [5]. User experience (UX) has been defined as "the combined experience of what a user feels, perceives, thinks, and physically and mentally reacts to before and during the use of a product or service" [18]. How women would prefer to interact with their safety wearable device in case of an emergency is an important factor to consider when designing the user experience for wearables. The types of interaction should feel natural to the users and "rely on simple gestures and taps, accompanied by immediate feedback" [13]. The aim of research projects in Human-Computer Interaction (HCI) is usually to design a system to enhance a given experience [2]. Therefore, in this research project, we designed and developed a wearable prototype, BSAFE, with two input modes, Press and Tap. The feedback to the user is in form of vibration. The focus of our study is on evaluating the women's experiences when interacting with the prototype and identifying their preferred method of interaction.

This research paper is organized as follows: The Related Work section provides a literature study of current technologies, the existing gap. The Methodology section describes the design and development of the prototype, BSAFE, and defines a set of criteria for evaluating the user experience. The Results section provides the final results to verify the hypotheses. The Discussion section discusses the results and provides observations. In the Conclusion section, the contributions made by this research to the field of HCI, the future work, and limitations are discussed.

RELATED WORK

In this section, we provide an overview of the existing research in regards to safety devices for women.

Mobile Applications

One safety android application is ABHAYA. The user can press the start button to activate the application. This, in turn, sends a message with the location Uniform Resource Locator (URL) to the registered contact numbers of the user. The application also makes a call to the primary contact number and continuously tracks the user's location every five minutes by sending a Short Message Service (SMS) with location URL to the registered contact numbers until the stop button is pressed [7].

Embedded/Hardware Systems

One wearable safety device for women is an undergarment called Society Harnessing Equipment (SHE). This device is embedded with electric shock circuit board, sensors, GPS and GSM modules. The sensors placed around the bust area can detect excessive force. The electric shock circuit board can deliver up to 3800 KV of electric shock to the attacker. It can also send a text message with the location of the user to the police and friends [11]. Another safety device is Suraksha, which is designed for women in India. The user can activate the device by voice (via voice recognition system), switch (via pressing), or shock (via force sensing resistors when the device is thrown on the ground) sending the location and SMS to the police and a registered mobile number through a Global System for Mobile communication (GSM) module [9]. FEMME is a safety device comprised of an ARM controller (for the hardware device) and an android application. By a single click on the Emergency button, the registered contact numbers and the police receive the location (latitude and longitude) of the user along with a distress message. By double clicking, the registered contacts receive a distress message and the audio will be recorded. If the button is long pressed, police will receive an emergency call and a distress message. This system has a hidden camera detector that can detect hidden cameras and notify the user (via a message), and a video recorder capable of recording the incident [10]. "Smart Foot Device" is another wearable safety device that can be attached to the women's footwear and triggered when she feels unsafe. The woman taps her left foot with her right foot four times and the registered contacts on her smartphone receive an alert message with her location [12].

Wearables

One safety wearable device is "SMARISA". This is a Raspberry Pi based wearable ring. It is based on Internet of Things (IoT) and comprises of Raspberry Pi Zero, Raspberry Pi camera, buzzer and button. When the user is in danger, she can press the button on the ring to trigger the Raspberry Pie. This enables the camera and the buzzer. The camera records the crime scene and the buzzer produces a loud alarm to draw attention to the user. The police and the registered contacts receive a help message with the current GPS location of the user and the link to the image (of the crime scene) through an android application [8]. Another wearable safety device uses stress levels (through monitoring skin resistance and body temperature) and body position (i.e., sitting, standing, sleeping, and struggling) together to predict if a woman is in danger. This device continuously monitors the user's physiological signals such as galvanic skin resistance (through skin resistance sensor) and temperature (through temperature sensor), and body position (through triple axis accelerometer) in real-time. The device simultaneously analyzes the collected data and uses a machine learning algorithm to predict if the person is danger. If it predicts danger, it will send an alert (in form of a tweet) to the designated person [4]. The design of another wearable safety device is based on Internet of Things (IoT) and machine learning. This device contains temperature and pulse sensors that collect physiological data from the user in normal and dangerous conditions and sends it to Cloud to train the machine learning algorithms. The system can automatically detect danger (using machine learning algorithm) based on woman's pulse rate and temperature. Through GSM and GPS, the device calls and sends alert message with the location of the user to the registered contacts [6]. A prototype named MoveFree consisting of a wearable sensor band (embedded with five biometric sensors) is another safety wearable, which is implemented in android. The prototype is based on pervasive computing features, which are continuous monitoring and context awareness. The system continuously monitors woman's physiological signals such as heart rate, breathing rate, blood flow rate glucose content, and sweat. The user's smartphone receives the collected physiological readings as contexts. If the woman is in distress, the physiological readings will be different from the normal readings. The MoveFree application will detect danger with the help of a decision tree and the registered contacts of the woman will receive a SMS. The nearest police station will also receive an alert SMS [16]. The "SafeBand" system, is another wearable safety device designed for women in Bangladesh. It is comprised of a wearable band with a LED light and two mobile applications that can be

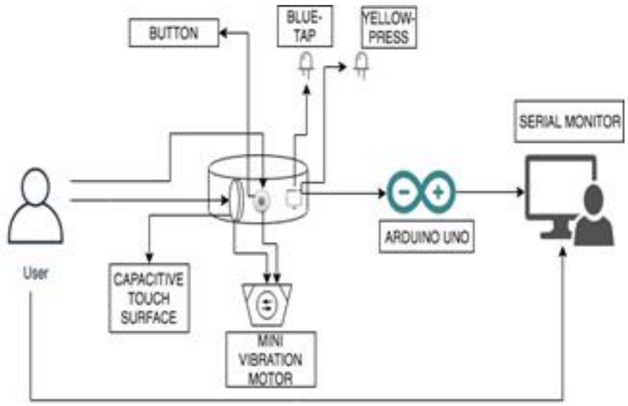

Figure 1. Architecture of the 'BSAFE' System

used by the user and the police. When the user presses the Danger button, the nearest police station and the registered contact numbers receive a
message with the user's location. The system has an acknowledgement feature enabling the police to acknowledge the user. This will turn on the LED light. The police presses the button "Final Acknowledgement" after rescuing the user [5].

User Experience

None of the above mentioned related work, except "SafeBand" [5], conducted a usability study of their system. The main focus of the above research was on the technical aspects of the product (i.e., the design and development of a system or a prototype), not the user experience. It is evident from the existing literature [4, 5, 6, 7, 8, 9, 10, 11, 12, 16], that there is a need for a user centric approach in the design and development of women's safety devices. In this research paper, we focused on women's experience when interacting with the wearable safety device. Through a user study, we identified the women's preferred method of interaction.

METHODOLOGY

Our research aims to verify the following hypotheses:
H1. Pressing is women's preferred mode of input
H2. Pressing results in less error

In order to verify the hypotheses, we (1) designed and developed a simple yet effective prototype, BSAFE, with two interaction modes, Press and Tap, (2) defined a set of criteria for evaluating the user experience with the prototype, and (3) conducted a user study. This section describes the design and implementation of the system.

Design and Development

The development of 'BSAFE' includes the implementation of both the hardware and software interfaces (Figure 2).
Hardware Interface - Arduino Uno R3 USB, Microcontroller kit, Adapter – 5V, Mini vibration motor, LEDs, Jumper wires, Cables and Connectors, PCB and Breadboards, 10 ohm Resistors.

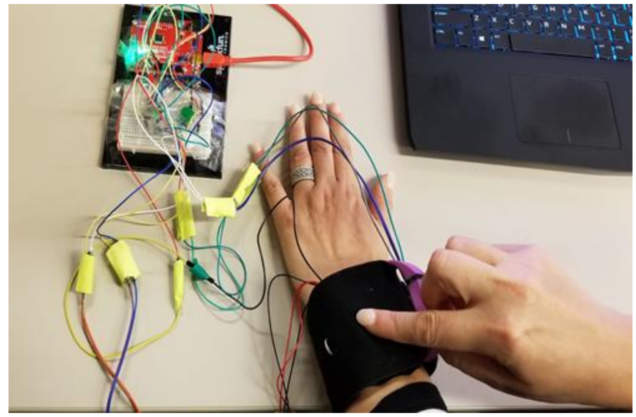

Figure 2. Prototype 'BSAFE'

Software Interface - The implementation of our system was done using Arduino IDE version 1.8.8.

The prototype was designed with the main objective of revealing which mode of input (Tap or Press) of a wearable safety device is more preferred by a woman in a distressed situation. Moving further within the development phase, the whole procedure of designing the prototype can also be represented in the architecture diagram (Figure 1).
The microcontroller provides modes for input and output digitally through 15 pins. A 10 ohm resistor was used for providing high sensitivity for the capacitive touch surface. A 5V adapter acted as a power source for the device. The button was used for input in context of Press whereas the capacitive touch surface was placed to detect the touch in context of Tap. In addition, a mini vibration motor was used to provide a vibration feedback whenever an input signal was detected. There are two LEDs in the prototype, yellow and blue to provide flashing feedback at the time of an input event. The yellow LED was used to provide acknowledgement for the Press mode of input whereas the blue LED provided feedback for the Tap mode.
The initial step was to make connections within all the components using the jumper wires, which in this case consists of three parts:

1. To make the connection of the button as well as the capacitive touch surface with the Arduino board.
2. To make the connection of LED lights in the bracelet with the Arduino board.
3. To connect the mini vibration motor with the Arduino board.

The Arduino board was connected to the PC using a USB cable. After these connections, we programmed the Arduino board using Arduino Integrated Development Environment (version 1.8.8) and we set the pin number and commands for mode selection with its respective outputs. The button was connected to the Arduino pin and programmed so that when the user selects the Press mode it will send signals to the Arduino. The Arduino board was connected to the pin providing command to the yellow LED and the vibration was initialized. This signal further runs the output phase of the program, which results in printing the alert message on the console. The whole process ran simultaneously with a yellow LED flash and vibration feedback to the user as well as an alert message on the serial monitor of the Arduino IDE console whenever the Press mode was selected.

On the other hand, to produce a signal for the Tap input mode, the touch sensor had to be tapped twice. Sometimes the user was continuously holding on the capacitive touch surface or tapping once, which produced errors. The touch sensor was made up of a wire joined through Arduino board and externally connected to the metal surface of the bracelet. This enabled it to act as a one plate of capacitor and our body in contrast acted as another plate of capacitor to release charge. This resulted in vibration and flash of the LED lights to the user. The time calculated by Arduino, which produced a signal and an alert message on the serial monitor simultaneously. If the user tapped once or held the touch surface of the prototype, it produced a false alert and blinking blue LED. It also produced a vibration in rapid continuous motion with no alert message.
Materials used in assembling the components in form of a bracelet: We placed our push button, mini vibration motor, the capacitive touch surface, and two LEDs inside a sports wristband connected with wires to the Arduino board.

Experiment Design
We focused on an empirical study to evaluate women's experiences using the input modes, Press and Tap, while interacting with the prototype BSAFE. We aimed at verifying the following hypotheses:
H1- Pressing is women's preferred mode of input.
H2 - Pressing results in less error.
Independent Variables: Press, Tap.
Dependant Variables: Satisfaction, Error rate.
We calculated qualitative and also subjective measures by using pre-questionnaires, post-questionnaires, interviews, and observations. The controlled experiment was conducted at the Usability lab, HCI room 3112, at Carleton University located in Ottawa, Canada.

Study Procedure
At first, participants were briefed about the purpose of this study and their roles. Participants were also ensured that this study is for assessing the system and not for evaluating the participants. The researchers informed the participants that the study sessions (number of trials and errors) will be noted. The total task completion time was 30 minutes. We collected the participants' demographics by using pre-questionnaires. The experiment process had the following sessions:

Training session
Before starting the experiment, the researchers demonstrated to the participants how to use the prototype. The participants were encouraged to ask questions before the experiment began.

Test session
Test sessions included two tasks. The study used within-subjects design, meaning each subject experienced all levels of the variable. The participants performed each task ten times.
Task 1: We asked the participants to wear the prototype on their non-dominant hand. The task, Pressing, was accomplished by using their dominant hand (they could sit or stand based on the task allocation by the researcher). They were instructed to imagine that they are in a dangerous situation and should access their safety device by pressing the button to get help. The participants felt a vibration acknowledging them that their message was sent.
Task 2: We asked the participants to wear the prototype on their non-dominant hand. The task, tapping, was accomplished by using their dominant hand (they could sit or stand based on the task allocation by the researcher). They were instructed to imagine that they are in a dangerous situation and should access their safety device and tap on the button to get help. The participants felt a vibration acknowledging them that their message was sent.
To avoid bias, the subjects were divided into randomized groups, Group 1 and Group 2. Group 1 had performed task 1 first in sitting position and then task 2 in standing position. Group 2 had performed task 2 first and in sitting position and then task 1 in standing position.

Qualitative Data
We collected qualitative data through the use of post-questionnaires, interviews, and observations. All the participants were asked to complete a set of post-questionnaires (a mix of Likert scale and open-ended questions). The post-questionnaire included six questions for each independent variable (Tap and Press). The questions were related to a) satisfaction level, b) ease of use, c) easy to learn, d) confidence level, e) willingness to use the system in future, and f) recommendation to others. The users were requested to rate their level of satisfaction on a scale of 1 to 5 (1 for very unsatisfied or strongly disagree and 5 very satisfied or strongly agree). In the post-questionnaire, we also asked the participants about their preferable mode of interaction, why did they have that preference, and where on-body they prefer to wear the safety device. Apart from these, all participants were asked to share their experience about the device.

RESULTS
We present qualitative analyses through the lens of Human-Computer Interaction (HCI). The user study was carried out to measure the user's experience by rating the following: satisfaction level, ease of use, ease of learn, how confident they were while using the system, willingness to use, and recommend the device to others. In our research Press and Tap are the independent variables and satisfaction and error rates are the dependent variables.
This section briefly discusses the participants' profile, hypotheses and analyses of the study.

Participant's Profile

The study was conducted with 17 female participants aged 18-35 with 88% of participants aged 18-25, 6% aged 25-29 and 6% aged 30-35. Fifteen participants were right-handed, one was ambidextrous, and one was left-handed.

Data Analyses

Satisfaction

The analysis of data illustrates that for the Satisfaction level of the input mode Tap, 29% of participants were very satisfied, 24% of participants were satisfied, 41% of participants were neutral, and 6% of participants were unsatisfied with the product. No one indicated that they were very unsatisfied. However, for the input mode Press, 35% of participants were very satisfied, 53% of participants were satisfied, and 12% of participants were neutral. No one indicated that they are unsatisfied or very unsatisfied. The analysis illustrates that for the Ease of Use level of the input mode Tap, 24% of participants were very satisfied, 35% were satisfied, 29% were neutral, 6% of participants were unsatisfied with the product, and 6% of them mentioned that they were very unsatisfied. On the other hand, for the input mode Press, 82% of participants were very satisfied, 12% were satisfied, and 6% of participants were neutral. No one mentioned that they were unsatisfied or very unsatisfied. The analysis illustrates that for the Easy to Learn level of the input method Tap, 41% of participants were very satisfied, 29% of participants were satisfied, 18% of participants were neutral, and 12% of participants were unsatisfied with the product. No one mentioned that they were very unsatisfied. Furthermore, for the input mode Press, 88% of participants were very satisfied, 6% of participants were satisfied, and 6% of participants were neutral. No one mentioned that they are unsatisfied or very unsatisfied.

The analysis illustrates that 24% of participants strongly agreed with the level of Confidence felt during the use of the input method Tap, 41% of participants agreed with the level of Confidence felt, 24% of participants were neutral, and 12% of participants disagreed with the level of Confidence felt. No one mentioned that they strongly disagreed. Moreover, 35% of participants strongly agreed with the Confidence level felt for the input mode Press, 35% of participants strongly agreed, 59% of them agreed, and 6% of participants were neutral. No participant mentioned that they disagreed or strongly disagreed. The analysis illustrates that for the level of Willingness to use the system in the future, for the input method of Tap, 35% of participants strongly agreed, 29% of participants agreed, 29% of participants were neutral. No one mentioned that they strongly disagreed. For the input mode Press, 35% of participants strongly agreed with the Willingness to use the system in the future, 41% of participants agreed, and 24% of participants were neutral. None of the participants mentioned that they disagreed or strongly disagreed with Willingness to use the system in Future. The analysis illustrates that for the Recommendation to others level of the input method Tap, 29% of participants strongly agreed, 41% of participants agreed and another 29% of participants were neutral. None of the participants disagreed or strongly disagreed with Recommendation to others. And for the input mode Press, 29% of participants strongly agreed with Recommendation to others, 47% of participants agreed, and 24% of participants were neutral. None of the participants mentioned that they disagreed and strongly disagreed.

A significant number of participants found that the input mode Press was very easy to learn and use when compared with the Tap input mode. They were confident to use the Press input mode and were willing to use the similar mode in future. Figure 3 and Figure 4 show the graphical representation of the user experience for input mode Tap and Press respectively.

Error Rate

The number of flaws identified from the log file and manually noted by the researchers during the study sessions helped to understand the user error rates. The errors occurred when the participants did not Press or Tap properly, tapped once, or tapped more than two times. The standard error of mean for Tap is 0.174 while the standard error of mean for Press is 0.095. The result shows that Tap input mode is more prone to errors. Figure 5 shows graphical representation of error rates.

Hypotheses Verification

According to the analyses and findings, we summarized our hypotheses verification as follows:

H1- Pressing is women's preferred mode of input.

H2 - Pressing results in less error.

DISCUSSION

From the post questionnaire and the findings, we understand that 52.94% of participants strongly preferred "Press with Feedback", 17.65% of participants slightly preferred "Press with Feedback", 17.65% of participants slightly preferred "Tap with Feedback" while 11.76% of participants strongly preferred "Tap with Feedback". Furthermore, 70.58% of participants selected their preferred mode of interaction because of its ease of use while 23.53% of participants chose theirs as they made less mistakes with that mode of input. Moreover, when asked where on body they would like to wear their safety wearable, 70.59% of participants selected wrist, 11.76% of participants preferred to wear it as a ring, and another 11.76% answered they would prefer to wear it as any type of jewelry. However, only 5.88% of the participants answered they would prefer to attach it to their clothes. 94.11% of the participants noted that the device is very reliable and the rest 5.88% were not sure of its dependency.

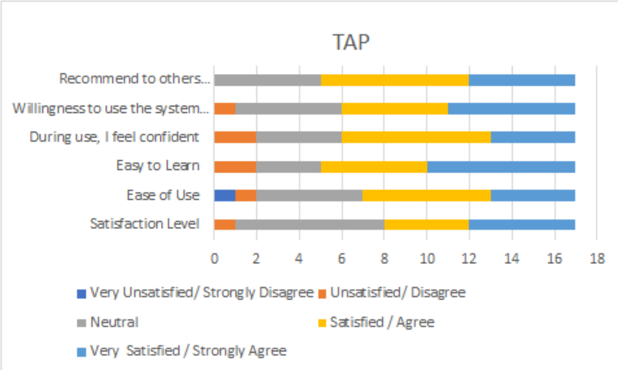

Figure 3. User Satisfaction graph with Tap input mode

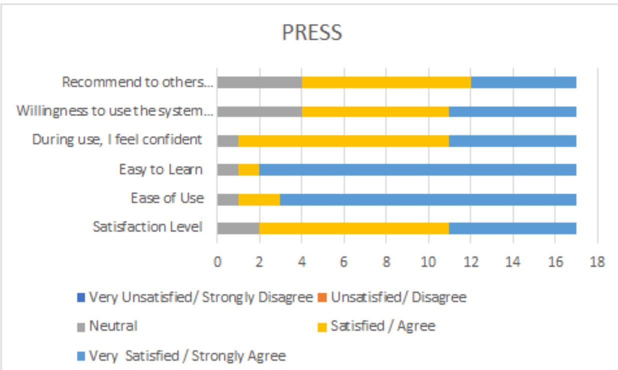

Figure 4. User Satisfaction graph with Tap input mode

CONCLUSION

We explored how women would prefer to interact with a wearable safety prototype given two input modes, Press and Tap. For the purposes of our user study, we designed and developed a prototype, BSAFE, with two input modes, Press and Tap. We evaluated the user experiences in the lab through a controlled experiment and collected qualitative data through the use of pre-questionnaires, post-questionnaires, observations, interviews, and log files. Based on our findings, we concluded that women's preferred mode of input is Press and this method of interaction results in less errors. Also, we found out that a large number of participants prefer to wear their safety device on their wrist. Evaluating and identifying the women's preferred method of interaction with a wearable safety device is a novel study. The empirical data gathered from the user study makes an empirical contribution to the field of HCI. Moreover, the identification of the women's preferred on-body location of a wearable safety device is another contribution that this paper makes. The above contributions will help the future researches and designers with the selection of the interaction method and on-body placement of the safety device that is most preferred by women. As for the future work, improving the current prototype functionality to send SMS message to the designated group of people with the location of the user . More input modalities like voice or gesture sensing can also be explored.

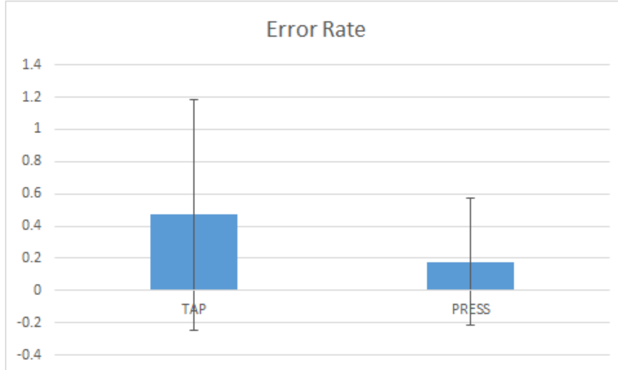

Figure 5. Error rate graph Figure

Limitations: One of the limitations we faced was not being able to recruit participants over 35 years of age for our user study.

Another limitation was that we were not able to conduct a field study to evaluate the user experiences in the real world. Moreover, in the controlled experiment we conducted in the lab, we asked the participants to imagine that there were in a dangerous situation before interacting with the prototype. Putting the participant is a distressed situation for the purposes of the study was not possible. How this can be done in a lab setting without causing an emotional distress to the participant needs to be investigated further.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. Girouard for her continued support and all the participants who took part in the user study.

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