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Hepatic Feedback: A More Effective Form of User Feedback in Location of Exit Points Detection in Disaster Situations

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ABTRACT:*Quality of feedback is a crucial aspect of user task performance in Human Computer Interaction (HCI). Designing systems that amplify the user's performance need cognizance of the various forms of feedback available, determining their strengths, weaknesses and suitability. This study enquires into the performance gains that can arise from using feedback. Until recently, this mode of feedback has been poorly explored and utilized. However, a number of studies show a significant amount of subjective advantages intrinsic in it, due to its intuitiveness. In this study, three users were evaluated in a disaster case scenario. Their task of locating exit points was aided by the various feedback modes, which include: Visual, haptic and a hybrid of both. The translation of these cues towards boosting their task efficiency and execution time were used to judge the relative effectiveness of these feedback modes. The experiment was carried out making use of a test-bed application. The design conceptualization of a TestBed application called "Rescue Mission" was developed in this research.A prototype was built to test and determine the effectiveness of vibration feedback, afterwards a comprehensive description of the prototype from the ideation process to implementation was incorporated. Evaluation, findings and future improvements for this research will be provided.The methodology used in building this application is Rapid Application Development (RAD).*

KEYWORDS:*Psychophysical, Feedback, Effectiveness, Perception, Stimuli, Thresholds.*

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I. INTRODUCTION

Coxswaining through safe paths in disaster environments is a very difficult task, probably because of lack of a lucid understanding of the internal workings of the sense of touch which has, until recently, largely made people suffer from a severe case of impairment in the virtual space (Davidson 2007). This cold and unfeeling space entirely bereft of any form of expression or perception of tactile stimuli has not only alienated those with potent visual and acoustic senses, it has consistently denied access to those without them. Today, it is not only a possibility to "feel" in the virtual space, it is also becoming commonplace and a consistent property of contemporary systems. Wu (2010) describes this state of affairs as a transformation that has been made possible by the advanced studies in the field of haptic.

Over the years, humans have characteristically relied on visual and audio senses while interacting with devices and their immediate environment. Although, it has recently been discovered that the human sense of touch is equitably as profitable and efficient as visual sense and proficient enough for assisting humans to grasp motion and properties such as vibration and texture respectively, while interacting in an environment (Ricky et al., 2010).

Saddik et al., (2011) describes the medical field as one area that has notably felt the supportive touch of technology. This new form of interaction has come with a great deal of benefits for the field especially in surgery. Surgeons are finding the more realistic interaction to be cost effective in their practice of various surgical procedures. An example is an Open surgery simulation hardware development project by Novint

Technologies Incorporation. Novint designs and builds, or 3D touch devices and software.Novint developed a 7-degree-of-freedom hardware system based on the Novint Falcon device, for use in conjunction with an open surgery simulation application (Novincustom.com, 2014). The 7DOF device gives users sensing in three rotational angles, giving the user the ability to pitch, yaw and roll the attached tools. The surgical instruments that are being attached are sensed and give feedback as well. This is leading to a greater degree of expertise for surgeons. Patients have also benefitted indirectly from benign surgical procedures as a result of increased skill level of surgeons.

Before we continue, let us take a short leave to define the word hapticsand its accestorisation.Haptics deals with the branch of science that explores the sense of touch. In the words of Saddik et al (2011):

"haptics is the science of sensing and manipulation through touch. He went further to state that "multiple disciplines such as biomechanics, psychophysics, robotics, neuroscience, and software engineering converge to support haptics, and generally, haptics research is done by three communities: the robotics community, the human computer interface community, and the virtual reality community".

According to Saddik (2011), the term haptics was derived from the Greek word "***haptesthai***" meaning "of or relating to the sense of touch," refers to the science of manual sensing (exploration for information extraction) and manipulation (for modifying the environment) through touch. It has also been described as "the sensibility of the individual to the world adjacent to his body by the use of his body".

According to Burdea, (1996), haptic was introduced at the wake of the twentieth century by researchers in the field of experimental psychology to refer to the active touch of real objects by humans. In the late 80s, the term was redefined to amplify its space to include all aspects of machine touch and human–machine touch interaction (Sears and Jacko, 2008). The 'touching' of objects could be done by humans, machines, or a combination of both, and the environment can be real, virtual, or a combination of both. Also, the interaction may or may not be accompanied by other sensory modalities such as vision or audition. Currently, the term has brought together many different disciplines, including biomechanics, psychology, neurophysiology, engineering, and computer science, that use this term to refer to the study of human touch and force feedback with the external environment.

This research recognizes the growing prominence of interaction in various aspects of life. It seeks to further explore and push its boundaries to discover the limits of its strength. It seeks to test the possibility of it being a more effective form of user feedback to users interacting with a system in the task of locating an exit location in a fire disaster scenario (Iwata, 2008).

II. DESIGN CONCEPT AND FUNCTIONALITY OF THE APPLICATION

The objective of this TestBed (Rescue mission) is to test the relative effectiveness of feedback in transmitting force information to a user and thereby enhancing task performance in a disaster scenario or situation. To attain this goal, developing an interactive system that allows exploration of the visual feedback modalities is necessary (Kühnel, 2012). For the same reason, two scenarios (path-finding and shape detection) were proposed. We tested the two scenarios mentioned above, to achieve the objectives of the research. The objectives of the research are as follows:

i. To test the effectiveness of visual against tactile feedback by directing users through a path by means of curvature detection and to compare the efficacy of feedbacks in the location of exit points;
ii. Also, to create an instance that showcases the efficacy of tactile feedbacks in aiding user performance or vice versa.

With the use of a tangible object called the VibroBox (further details will be given in the following section), this system will have the capacity to deliver force information in response to the user's movement within the virtual space. Using this Vibro-Tactile information, the user is able to tell the proximity of an exit point. Effectiveness will be established in this experiment through measurement and comparison of the values of the earmarked variables. Utilizing shape detection and path finding for the result of this research, object perception and curvature detection of users will be evaluated in three different states. In the first instance, proposed users will attempt the task through the guidance of visual feedback alone. In the second activity, two feedback approaches will be done. This will be carried out to test if the addition of visual feedback is a viable option for improving user performances in carrying out task or not. The same task will be reiterated using Vibro-Tactile feedback alone. This is done to measure the efficacy of feedback in the guidance of users in detecting exit or escape routes in disaster scenarios.

As shown above, with the aid of a thoughtful TestBed (Rescue Mission), this research will analyze the contrast in the results of visual feedbacks, visual and Vibro-Tactile (bimodal) in virtual shape detection and way finding.

A distinctive feature that the research conceptualized to make certain that the test bed is optimizing the feedback modes, guiding the user in accomplishing the task (way finding and shape perception) was the use of a blank image as an interface of the test bed (Rescue Mission). Users are then directed by the feedback modes they select to accomplish their task.

Numerous ideas have been suggested and aborted before the derivation of this final concept "Rescue Mission". The initial idea was to design a test scenario that will test the effectiveness of feedback in the detection of landmines. Nevertheless, as a result of an in-depth study carried out, it was deduced that the technology may not be viable or best suited in this case. This is because landmines are usually placed at random. In a study made by (Kelly, 2003), it was suggested that during war situations, the land mines are often placed indiscriminately over a large geographical area. Hence, using way finding and shape detection activities may be futile to the research. Consequently, several brainstorming sessions were made, and the team came up with a more practical research scenario that will be suitable to test for the effectiveness of feedback. In a research about human behavior in disaster situations, the judgment of people in the state of fear tends to be clouded by panic and confusion. It is in this light that we decided to come up with a scenario that will test the efficacy of feedback in the evacuation of people in disaster situations.

To efficiently guide or aid the navigations of users in the environment, several vibration patterns and colours will be implemented to provide necessary and adequate feedbacks. This may be said to have aided consistency and fair evaluation between the forms of feedbacks used in this test bed. A supporting study by (Sreng et al., 2009) showed the importance of different patterns of vibration and its use in conveying the impact position of an object. This test bed uses different vibration patterns and colours for feedback measures to timely inform users about the turning points, caution and danger zones where necessary. The colours optimized as guides in the visual mode of feedback especially in the path-finding activity were red (danger zone), orange (caution area) and the green signaling right path, just like in the general traffic system. The research adopted the optimization of only three colours so as to reduce mental workload for users when carrying out a task and to aid user's memorability (Schvaneveldt and Reid, et. al., 1997). This, to a reasonable extent will reduce the rate of distraction users may encounter if they have to look somewhere else ("shift focus") in the test bed interface while carrying out a task.

For the test scenarios, there are varying intensities depending on the user's position relative to exit points. For instance, a mild vibration will signal a gradual departure from the correct route while a more intense force will continue to signal an increasing degree of variance. The strongest force will make known to the user a complete departure from the safe path. The device is configured to have these patterns and the user is expected to detect and interpret them simultaneously. To familiarize the users with the system and to enable them understand the meaning of these feedback, the research provides a demo similar to the main system.The feedback the user gets helps to guide and indicate to them their proximity to a particular exit point . A crucial aspect of this experiment is the perception of the stimuli that results from forces reflected from the virtual space which serve as event indicators . According to (Lenarčič and Wenger , 2008), the strength of the tactile stimuli and the timeliness of delivery are all crucial success factors for users relying on them. It is therefore vital to ensure that the device is properly calibrated in the algorithm to render this. There are four categories of devices namely: Vibro-Tactile, Pneumatic, Electro-Tactile and functional-neuromuscular (Delgado and Araki, 2005). This research employs the Vibro-Tactile type. According to Campion (2011), they are designed to apply a combination of high frequency and low amplitude to the hand.

In the palm area of the handis where contact with interface is made, this part of the body contains mechano-receptors known as the Pacinian corpuscles; these have a sensitivity range of 100Hz to 300Hz. This will guide calibration of the device for appropriate stimulation (Campion 2011). Based on this, the prototype will be tuned within this range/ threshold. Prior to the main test, each user will undergo a calibration test to determine a user's absolute and differential threshold. The values generated from the TestBed will be written to a file. This is a database system where the values will be stored in a remote location on the system used for the experiment. These values will then be collected to be used for final evaluation and analysis. The TestBed will be designed to collect the "Slip off time", "Off target" and "Approach time" respectively for every user. These measurement variables will be used to determine the effectiveness of the respective feedback modes.

III. PROTOTYPE

In the development of the prototype (**Rescue Mission)**, several functionalities were implemented to aid in effectively gathering the required data from both activities (Path Finding and Object Perception). These functionalities are as follows; menu navigation that will include; Demo, Calibration, Exit and TestBed Options. Danger Zone, Caution Zone, Turning Bends, colours depicting various vibration patterns and various feedback signs for feedback were incorporated to foster usability (Norman, 1998).

Furthermore, it was necessary to create ways for users to choose from the given options, which activity they want to attempt, for example, way finding or shape detection. Rescue Mission gives the users the opportunity to navigate and change activity at any given instance. These are fundamental components of a launch menu which grants the user control in the environment (Neilson, 1995).The analogy given in the preceding paragraphs are show in Fig. 1 (Rescue Mission State Diagram).

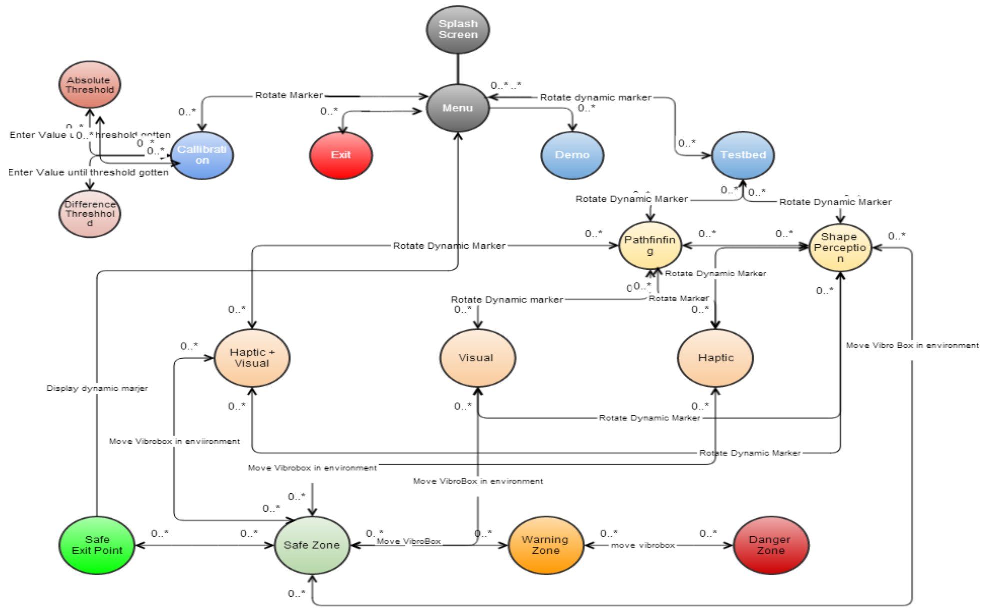

Fig. 1 (Rescue Mission State Diagram)

With the use of a dynamic marker attached to a physical object, users are able to navigate through the system by rotating it. This is aided with use of ReacTIVision. ReacTIVision is an open source, cross-platform vision

framework for robust and fast tracking of fiducial markers attached to physical objects

(www.reactivision.sourceforge.net, 2014). A dynamic marker will also be attached to a VibroBox that will aid the users in navigating through the TestBed environment especially when testing for feedback. The VibroBox is an object that allows the addition of Vibro-Tactile feedback into a user interface, in this case, a Tangible user interface. The VibroBox contains an Arduino board that has an attached vibrating actuator. In this context, the VibroBox serves as a device that relays Vibro-Tactile feedback when required, to the users in the course of the activity. Users carry out (navigate) their task with the VibroBox as the apparatus for movement. The diagram in fig. 2 shows the following as labeled: (1). VibroBox (2) External WebCam (3) Arduino Board (4) Fudicial Marker (5) Actuators and (6). USB 2.0 cable.

Fig. 2 VibroBox

IV. PROGRAM SPECIFICATION

The user introduces the marker into the environment and selects from the options provided in the menu. These options include; the calibration setup, the demo, the test bed and exit. Figure 3 and 4 below shows the Splash screen and selection pages of the TestBed.

Fig 3: Splash Screen

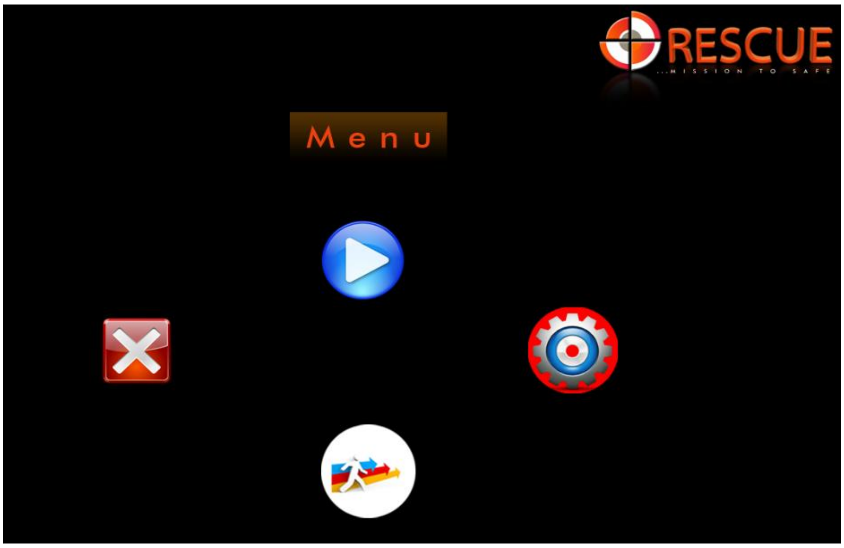

Fig 4: Main menu

Like earlier stated, the user has four options; the Calibration setup, Demo, TestBed and Exit.

4.1. Calibration Setup

In order to evaluate the different courses of action in this research accurately, it is useful to get accurate likelihood estimates of the alternatives (Cohen and Goldszmidt, 2004). Therefore, it is important to calibrate instruments as it improves its measurement performance. This helps to reduce measurement errors and the assurance of accurate measurements. Also, the sensory perception of users to vibration feedback has to be determined. This is used to gain cognizance as to what point or threshold different users feel vibration feedback. This will enable the TestBed to be set to these values. Fig. 5 shows the calibration options.

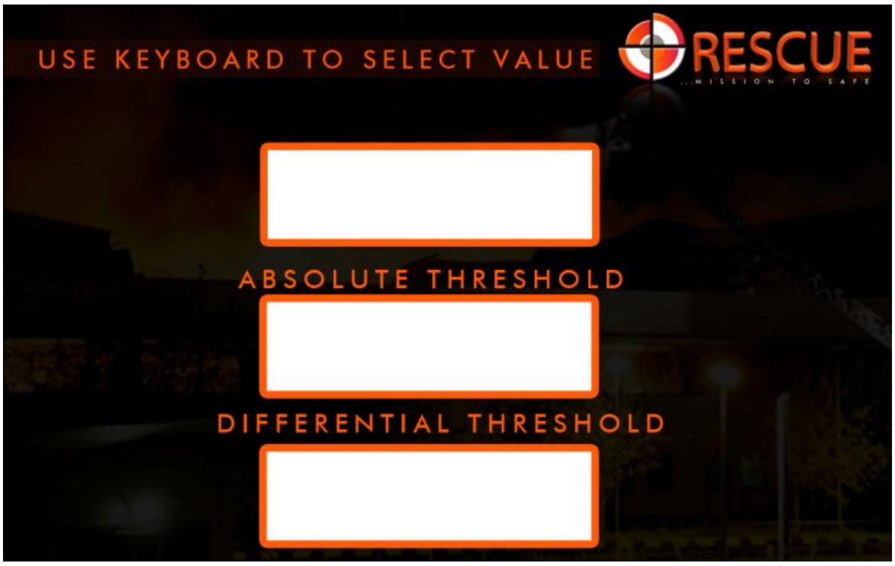

Fig. 5: Sensory/Vibration Threshold

For the sake of this experiment, a test for sensory thresholds for three users were done. An example of this was conducted by psychologist Ernest Weber at the University of Leipsig in Leipsig, Germany. This experiment was designed to determine sensory thresholds. This will also be optimized in this test. They include; The Absolute and Differential thresholds.

4.1.1. Absolute Threshold

Absolute threshold can be defined as the smallest intensity of a stimulus that has to be present for a stimulus to be detected.

4.1.2. Differential Threshold

A difference threshold otherwise called "differential threshold" is defined as the difference in value of two stimuli that is just ample enough for a noticeable difference. Table 1 shows the calibration results for the absolute and differential threshold.

Table 1: Calibration Results Table

Participants	Absolute Threshold	Differential Threshold
User 1	74	140
User 2	72	150
User 3	75	145
Average	74	145

Based on the results gathered in the psychophysical test, the TestBed is configured to relay vibration feedback upon these values for every participant of this experiment.

5.2. Demo

In order to familiarize the users with the TestBed, a demo, reminiscent to the TestBed was built. In this section, users are given firsthand experience on how to navigate in the TestBed environment. They also get to know about the visual cues provided and the meaning of the different vibration patterns.

5.3. TestBed

This is where the main experiment takes place. Before any experiment begins, each user is expected to have successfully completed the psychophysical test. After the psychophysical test, each user will have to go through the demo in order to familiarize themselves with the system. The users are provided with two scenarios. They include: Pathfinding and Shape detection. For the two scenarios, the TestBed had a blank screen (foreground). The blank screen is an important implementation in the Rescue Mission TestBed, as it has proven the credibility of the modes of feedback implemented by Rescue Mission. For example, on the mode of feedback, users are guided to carry out tasks with tactile force feedback.

The TestBed's interaction is done on a horizontal plane and a camera placed on a stand above the setup environment in the same space which will track the position and movement of an object with the use of ReacTIVision and fiducial markers. This method of coupling has many advantages according to (Shen, et. al. 1996).

A java based development environment called "Processing" was used in addition with Arduino (technology that have enabled the implementation of vibration feedback) to develop this prototype (Rescue

Mission). Processing was used because of its surplus libraries made available to portray all the sketches in the design conceptualization into reality. The libraries used to develop this prototype are as follows:

1. TUIO LIBRARIES:

voidaddTuiObject (TuioObjecttobj) {This is used in order to activate the approach timer function.}

Void updateTuioObject (TuioObjecttobj) {This was used for the purpose of updating the position of user in the TestBed environment. Also, it was optimized to transmit the coordinate of a user at the time, to a global variable.}

Void removeTuioObject (TuioObjecttobj) {This was used for the purpose of clearing values from the variable.}

2. APPLET LIBRARIES

turnOn () :

This was used for the purpose of turning on the intensity of the VibroBox.

turnOff () :

This turns off the vibration. It is called only when the user leaves the area where vibration feedback is not needed.

turnOnVal () :

This was used for the purpose of setting the intensity of the vibration, as well as increasing the vibration amplitude and frequency in different areas.

pulse () :

In order to set the vibration mode to pulsating vibration, this method was used. The pulse method was used to connote a bending corner in the TestBed application.

For the interface design, Adobe Photoshop was used. This was because this software is the industry's leading software for graphic design and had the tools needed to give appropriate look and feel to the TestBed application.

V. MEASUREMENT VARIABLES USED IN THE TESTBED

Three measurements variables where used for this TestBed application. They included: Slip-off time, off-target time, and approach time.

5.1. Slip-off time

Slip-off time was included to calculate the duration of time a user spends outside the borderline or safe zone. It keeps on reading until the user navigates back to the safe zone. The user at this point is alerted with appropriate feedback to get back on track. The average slip off time for each time the user slips off is gathered and is used to test the effectiveness of the feedback in the given scenario.

5.2. Off-target time

Off-target time was incorporated to calculate the number of times the user navigates completely off the safe and warning zone. These measurement variables were stored in a text file and were later used to do a quantitative analysis for the experiment.

5.3. Approach time

Approach time calculates the total duration a user uses in completing the given exercise using a particular feedback mode. It starts timing from when the user begins navigation in the environment to when the user finishes the navigation. This data is also used as a basis for analyzing the slip-off time duration which will be deducted from the overall approach time.

The **X and Y** coordinates were used in this TestBed to collect the object or user navigation at any point in time in the environment. As aforementioned, values generated here are stored in a text file for later use. The values are then used by calculating them with the slip off and the off target time, thereafter a graph is plotted using this values to test the effectiveness of respective feedback modes.The exit option offers users the opportunity to abort an activity at any point by pressing the "E" key on the keyboard.

Furthermore, at the beginning of the experiment, a text file that acts as a log is created. The text file accumulates the values of the measurement variable at every given time and is could be assessed after the completion of a task.

The implementation of the feedback modes in the test bed are achieved by creating and differentiating zones (areas) in the TestBed activity environment which prompts different forms of feedbacks in the environment. The feedback pattern must be consistent in order to make certain that an equivalent measure is given to participants irrespective of what method of feedback is opted for. This was accomplished using an image that has a green colour to define the right or accurate path. The orange colour was used to indicate the caution area and the red colour was used to depict the danger zone. The green colour gave a beeping visual cue to make the users aware of a bend.

Fig. 7: Screen Shot of Ongoing Experiment

VI. EVALUATION

The purpose of this evaluation was to test the effectiveness of tactile feedback as a more effective form of user feedback in location of exit points in disaster situation. After the test had been concluded for three users in six scenarios (three for Pathfinding and three for shape perception), their respective data was accumulated. The data was collected using a database. The Completion time, Slip off-time and off-target time were written to a file. These data was collected and a graph was plotted for each user in each scenario for each feedback modes. In order to ensure validity of the results of this test, some ethical decision making and research approaches as propounded by Macleod (2005) were followed. He posited the following questions to aid the validity of research:

i. Are we looking for the right things?
ii. To answer this we made sure that the scenario is representative of real world use. Disaster situation are everyday occurrences and answering the question of this research will prove the effectiveness of feedback in evacuation of helpless people in such cases.
iii. Are we collecting the right data?
iv. In answering this, we made sure that the specific data we were gathering was relevant to usability and quality of use
v. Are we analyzing the data appropriately?

To answer this we made sure that the analysis of the raw data could reliably deliver valid indicators of usability.

VII. PROCEDURE

The experiment was conducted in four different phases. Three users were students from Middlesex University. In order not to put the participants under pressure, we made sure that the room was void of people. This is because when respondents know that they are being watched, they often will say positive things and will be pressured to perform well. During the test, we also made sure that that we spoke well of the respondents, giving them reassurance and encouragement. This was very effective at helping users to feel more comfortable and express what they dislike. The following is a breakdown of the procedure for this experiment. First, each user was given instructions on how to use the TestBed. A demo session was provided to the users. They were given the opportunity to familiarize themselves with the system at this point. Upon completion, the participants were appreciated and debriefed.

1. Pathfinding

During this test scenario, the three users using a VibroBox navigated through the TestBed making use of the cues provided for the respective scenarios. The users were given adequate feedback at every point. This is shown in figures 8, 9 and 10.

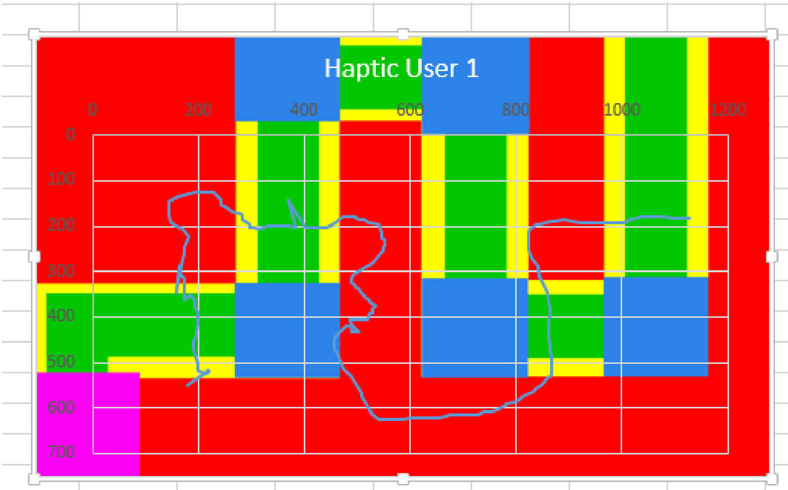

Fig 8: Graph showing Pathfinding Scenario for Haptic User 1

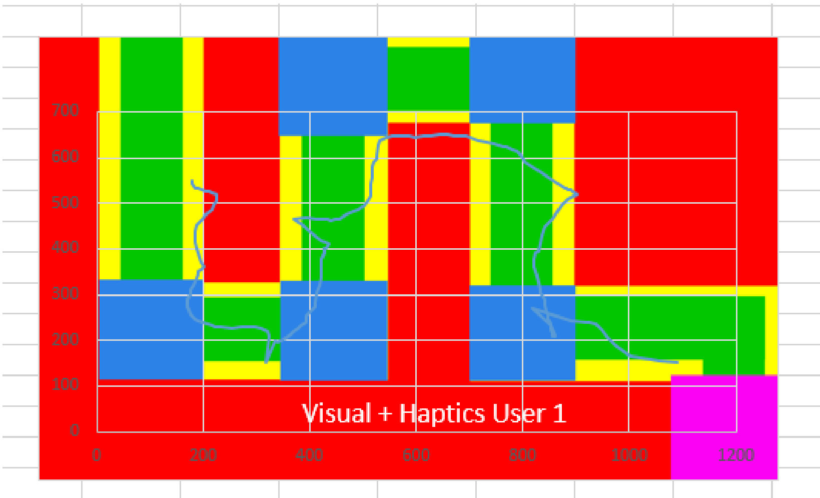

Fig. 9: Graph showing Pathfinding Scenario for Visual + Haptic User 1

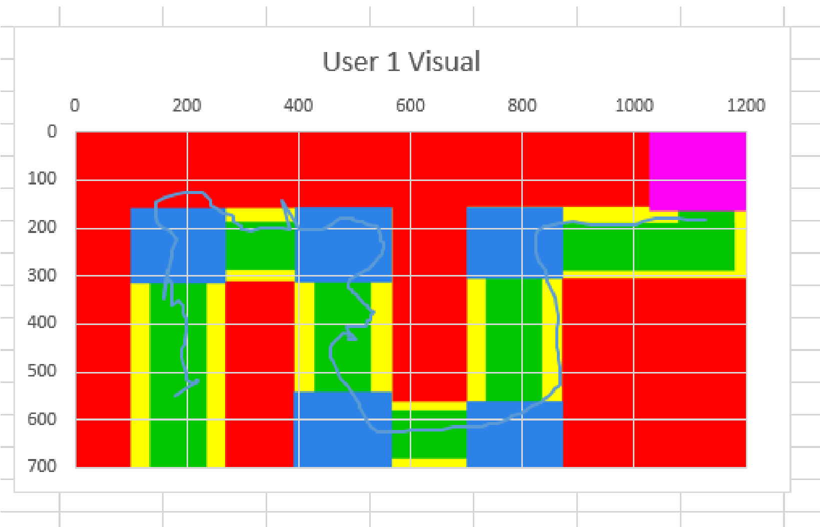

Fig 10: Graph showing Pathfinding Scenario for One User Visual

2. Shape perception

After completing the first scenario, we then did the test for the shape perception for each feedback mode. The first feedback mode was visual. The users had to follow the visual cues provided to navigate through rectangular shape. Appropriate feedback for the respective modes were given to each user.The diagrams are shown in figures 11, 12 and 13.

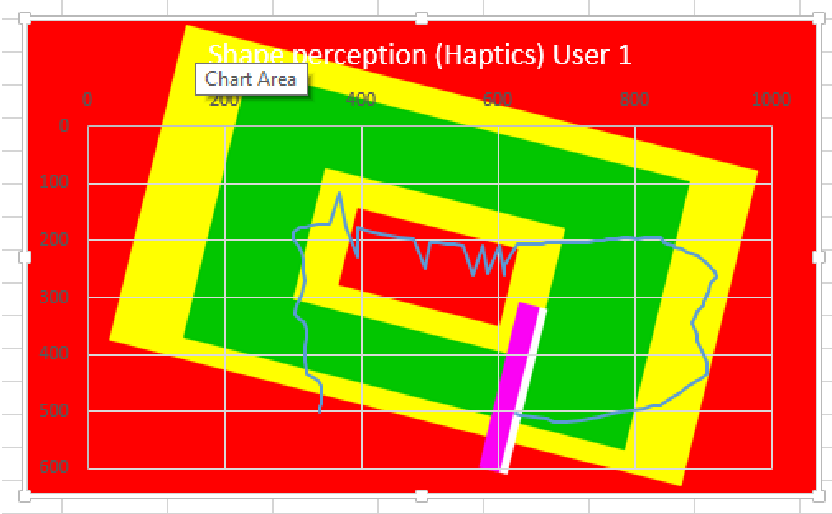

Fig. 11: Shape perception (Haptics)

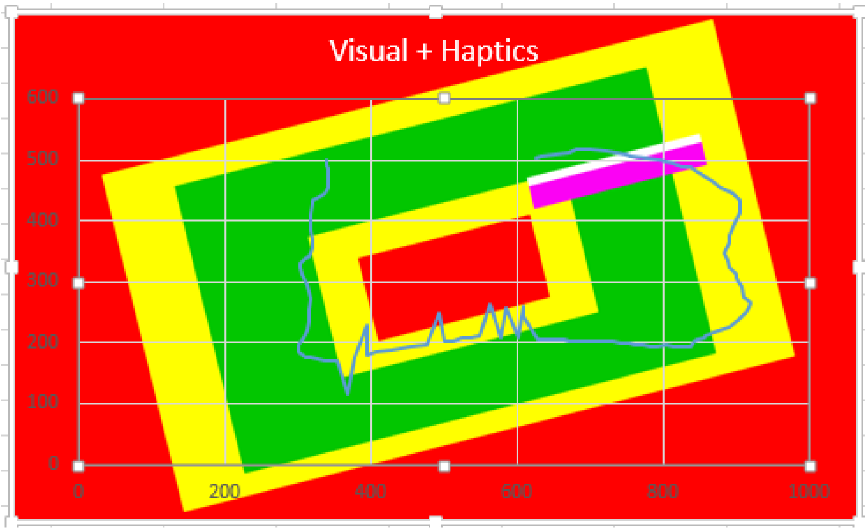

Fig. 12: Shape perception Visual + Haptics

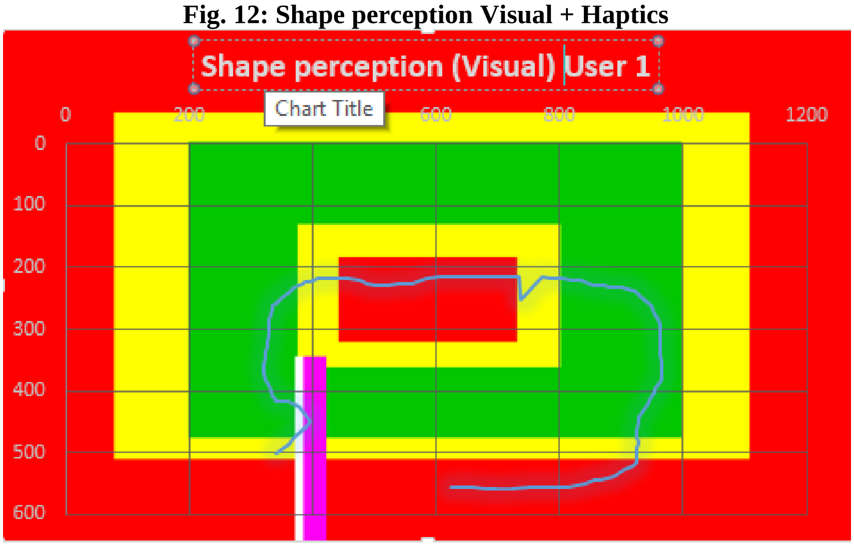

Fig. 13 Shape Perception (Visual) User 1

The following table show the results gathered from the calculation of the Approach time, slip off time and off target time.

Table 1: Completion Time

	Activities	Completion Time (Seconds)			
S/N	**Scenario**	**User 1**	**User 2**	**User 3**	**Average/Mean**
1	Pathfinding (Visual)	60.08	55.98	53.44	56.5
2	Pathfinding ()	67.76	66.75	62.07	65.52666667
3	Pathfinding (Visual +)	45.09	42.34	44.12	43.85
4	Shape perception (Visual)	58	53	52	54.33333333
5	Shape perception ()	56.67	45.88	47.66	50.07
6	Shape perception (Visual +)	44	37	32.66	37.88666667
	Total Time Spent by each user	**331.6**	**300.95**	**291.95**	**308.1666667**

Table 2: Off Target Time

	Activities	Off Target			
S/N	**Scenario**	**User 1**	**User 2**	**User 3**	**Average/Mean**
1	Pathfinding (Visual)	2	1	0	1
2	Pathfinding( )	4	3	4	3.666666667
3	Pathfinding (Visual +)	1	1	0	0.666666667
4	Shape perception (Visual)	3	2	1	2
5	Shape perception ()	4	5	3	4
6	Shape perception (Visual +)	2	1	0	1
	Total by each user	**16**	**13**	**8**	12.33333333

Table 3: Slip Off Time

	Activities	Slip off Time			
S/N	**Scenario**	**User 1**	**User 2**	**User 3**	**Average/Mean**
1	Pathfinding (Visual)	1	1.5	2	1.5
2	Pathfinding ()	4	2.25	3	3.08333333
3	Pathfinding (Visual +)	0.75	2.1	0	0.95
4	Shape perception (Visual)	3	0.76	0.88	1.54666667
5	Shape perception ()	4	3.75	3.2	3.65
6	Shape perception (Visual +)	2.3	0.76	1	1.35333333
	Total Time Spent by each user	**15.05**	**11.12**	**10.08**	**12.0833333**

The graphs on figure 14, 15 and 16 also show the results gathered from the calculation of the Approach time, slip off time and off target time of the TestBed.

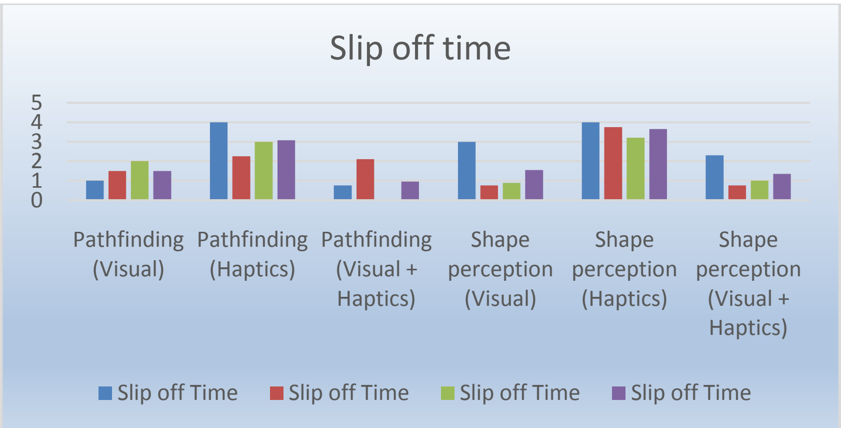

Fig. 14 Graph showing Slip Off Time

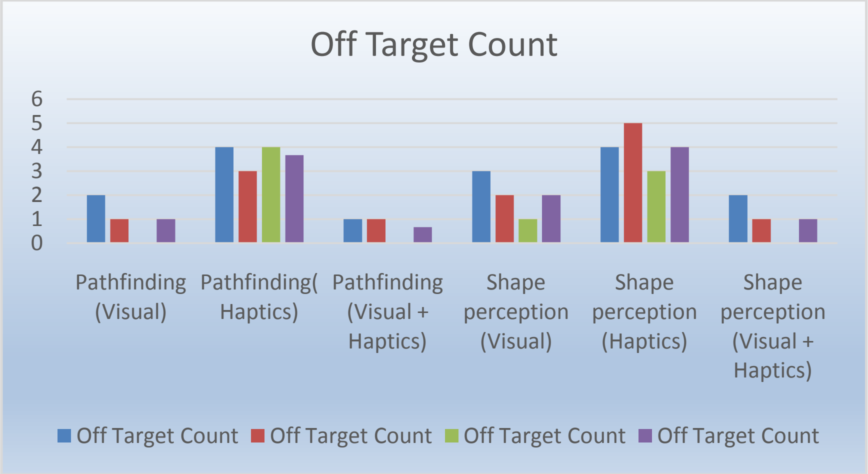

Fig. 15: Graph showing Off Target Time

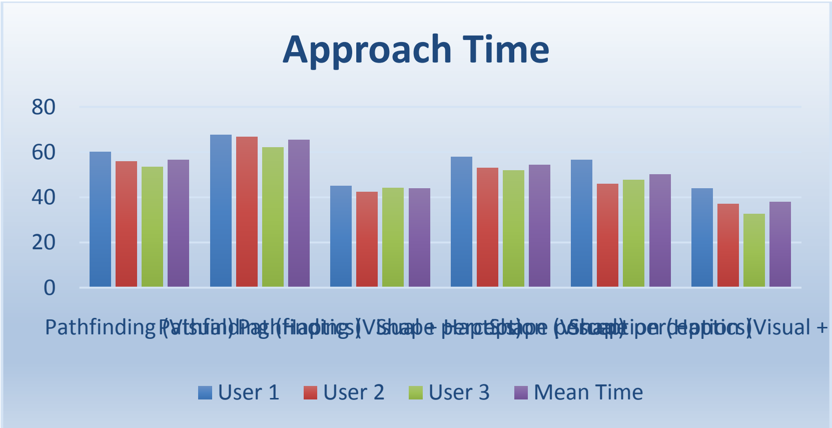

Fig. 15 Graph showing Approach Time

Based on this quantitative and graphical analysis, it has been deduced that a hybrid of and Visual feedback is much more effective for location of exit points in disaster scenarios. Alone has proven ineffective as users have found it difficult to navigate with this feedback mode alone.

VIII. REFLECTIVE CONCLUSION

The development of Rescue Mission was to examine the effectiveness of feedback as more effective form of user feedback in location of exit point's detection in disaster situation. However, not forgetting other forms of feedbacks, the purpose of this research was to determine the effectiveness of Vibro-Tactile feedback in way finding and shape perception. The TestBed and the evaluation processes have assisted this research and from the empirical case studies cited in this research, it can be said that feedback should in the future of technology be incorporated as vital part of "designs" for general use.

The TestBed application, "Rescue Mission", to the development team, has accomplished its aim. The processes from the conceptualization phase to the development of the prototype for determining this venture have therefore been adequately illustrated in this report.In the team, tasks were broken down and designated to each member of the team.

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