Assessing Effectiveness of Information Presentation Using Wearable Augmented Display Device for Trauma Care

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Abstract

Technological intervention that supports data transfer of sending summary of the patient vitals through the transfer of care would be a great benefit to the trauma care department. This paperfocuses on presenting the effectiveness of information presentation on using wearable augmented reality devices to improve human decision making during transfer of care for surgicaltrauma, and to improve user experience and reduce cognitive workload. The results of this experiment can make significant contributions to design guidelines for information presentation on small form factors especially in time critical decision-making scenarios.This could potentially help medical responders in the trauma care center to prepare for treatment materials such asmedicines, diagnostic procedures, bringing in specialized doctors or consulting the advice of experienced doctors and calling in support staff as required, and so on.

Keywords: Transfer of Care, Wearable Augmented Reality, Information Presentation, Usability.

1. INTRODUCTION

Small screen devices are foreseen as ubiquitous in the medical field especially in the fields of surgery and trauma care (Glauser, W., 2013). In this era, where the Internet of Things (IoT) is believed to be the future, augmented reality allows interaction between the digital and real world. It can deliver rich and meaningful digital overlay on the real world. The abilities of this technology are well identified and research is being done in different domains such as education, medicine, aviation, and so on (Schmidt, G. W., & Osborn, D. B., 1995; Casey, C. J., 1999, Szalavári, Z., Eckstein, E., &Gervautz, M., 1998; Casey, C. J., & Melzer, J. E., 1991; Foote, B. D., 1998). The purpose of this study was to analyze the effects of information complexity and mental workload on trauma care providers/surgeons during emergency response scenarios for augmented display devices. Using heads-up displays for medical responders in hospital trauma care can optimize the communication channel and information flow. Wearable devices such asGoogle Glass™, being a small form factor, poses challenges in presenting information in such a small screen and at the same time making sure that there is no cognitive overload for the user. Other challenges in small form factor devices include low information density that can influence the user's readability and optimum navigation to access the different features of the applications. Previous study by Ho et. al. (2016), found that when the interface was less cluttered and left justified it resulted in better legibility.

2. BACKGROUND

2.1 Transfer of Care

Trauma surgeons treat patient injuries which include falls, motor vehicle crashes, motorcycle crashes, assaults, gunshot wounds, stab wounds, burns, and so on.

Once a trauma case is reported, the information reaches the emergency team in the hospital and then air and ground transfer are assigned according to what was asked by the person who reports at the scene. The first responder on scene decides the urgency of care required and; the present emergency response protocols involve the information sent by first responders to the most appropriate trauma center around. The first responders provide a brief summary of what they observed on the ground such as: vital signs that they manually noted, pictures taken, any changes in vitals during the transport, any signs of pain in the patient's body, any kind of care given during transport, the type of incident that had been reported by witnesses, and the duration of transport. Patient evaluation is done by assessing the scenario, severity of injury, the first responder's knowledge repository, and emergency protocol(Shen & Shaw, 2004). Quality and timely organization of treatment during transfer of care is given by prioritizing patients based on severity of their injuries. The trauma center receives the updates only when the patient reaches the emergency department. The present system is chaotic and requires a desperate need to reduce response time(Carr et al., 2006). This would also require the transport vehicle (air or ground) to be equipped with an appropriate sensor network and a medium to transfer data smoothly to the trauma care center. Study suggests that air transfer is significantly faster than ground transfer when it comes to distances greater than 50 miles but for distances less than 50 miles there is no significant difference(Diaz et al., 2005). Studies report different response times like on scene arrival, on scene time and total response time (Frykberg& Tepas, 1988). Research by Guise et al., (2015) states that EMS relies on the knowledge repository of the personnel on clinical assessment, decision making, and so it would be important to add the doctor in the training of the EMS personnel.

Mobile health monitoring systems have been used extensively for triage purposes. Van Halteren et al. (2004) developed MobiHealth System which explains the different pros and cons of wireless network transmission of patients' vitals data. The system can support sensors and is connected through a body area network.

2.2 Information Presentation

In spite of the growing adoption of wearable devices, there is a lack of research on user interface design solutions to enable successful multitasking without information overload. Information can be classified into several categories such as text information, picture information, and sound information. In the case of text information, past research highlights the importance of information being presented in the right place at the right time. Information presentation has been used to study complex task decision making (Speier, 2006) and in mobile phone form factor (Ganapathy et al., 2011). Resultsfrom previous studies suggest that the relationship between information presentation format and decision making is moderated by the task complexity. Technological intervention that supports data transfer, in this case sending vitals from the patients during the transfer of care, would be a great benefit to the trauma care department. This would help the medical responder, in the trauma care center, to prepare the necessary treatment materials like medicine, diagnostic procedures, bringing in specialized doctors, obtaining consultation from experienced doctors, and calling in support staff if required.

2.3 Visual Search

Information presented in the wearable augmented reality devices involves activities such as browsing, text messaging, route navigation, reading and gaming. All these activities involve visual search that helps the user find the information they require. Hasegawa et al. (2008) found by subjective evaluation that increasing character sizes (2.5 mm, 2mm and 1 mm in height) resulted in an increase in legibility in computer screens and there was no significant difference in search speed for the different character sizes. Van Schaik& Ling(2001) studied the effects of background contrast on visual search performance in web pages and mobile devices, and they did not find any significant difference in performance. To measure mobile user information processing abilities while walking, a conventional serial visual search paradigm was used. Participants were instructed to search for a target ("T" shape) among distractors ("L" shapes) in different rotated orientations. They reported that the presence vs. absence of an irrelevant color singleton distractor in a visual search task was not only associated with activity in the superior parietal cortex, in line with attentional capture, but was also associated with frontal cortex activity (Eglin et al., 1991).

2.4 Wearable Technology

Previous studies related to users' attitude towards devices such as google glass shows that there are some concerns related to privacy and there is a curiosity towards access to information right then and there (Xu et. al, 2015). Google Glass has an optical head-mounted display, resembling eyeglasses; it displays information in a Smartphone-like manner, but provides a hands-free format that is controlled via voice commands and touch.The device is a wearable mobile computing device with Bluetooth connectivity to wireless internet access.The Glass display of 640 x 360 pixels rests above the line of sight such that the user's vision is not interrupted. The device comes with a storage of 16GB and 1GB RAM of memory. Applications for the device are developed on Android version 4.4. The device includes the following features: real time hands free notification, hands-free visual and audio instructions, instant connectivity access, instant photography/videography, augmented reality.

The potential medical dangers of head-mounted displays have been documented by Patterson et al. (2006)and include: decreased awareness of physical surroundings, visual interference, binocular rivalry with latent misalignment of eyes and headaches. The authors performed intense tasks on the device and noted that the surface temperature rises by 90% in 10 minutes of usage.

3. METHODS

The primary objective of this study was to a) explore how wearable augmented reality devices, such as Google Glass, can improve human decision making during transfer of care and b) understand the design of information presentation on the wearable augmented reality device to improve user experience, reduce cognitive workload and aid decision making. Hence an empirical study was conducted to support the hypotheses. The experiment was designed to be tested on a Google Glass as the wearable device. The pool of participants included physicians and residents from the Department of Trauma and Surgery, Boonshoft School of Medicine, Miami Valley Hospital, Wright State University, Dayton. Six residents (three junior and three senior) participated as novice and six physicians as residents. The experiment was divided into two parts – visual search task and patient vitals simulation task.

- Visual Search Task: This included testing participants with a visual search task for addressing the research question of how the design of information presentation on the wearable augmented reality device improves user experience, reduces cognitive workload and aids decision making.
- Patient Vitals Simulation: This included testing participants on multi-tasking and viewing streaming patient vitals data and decision- making. The participants were asked to take ATLS (Advanced Trauma Life Support) as the secondary task.

Fig.1, shows the experiment setup as the participant was viewing the stimuli. EEG data was collected through the Emotiv device to understand the brain response to visual search tasks as the stimuli was presented.

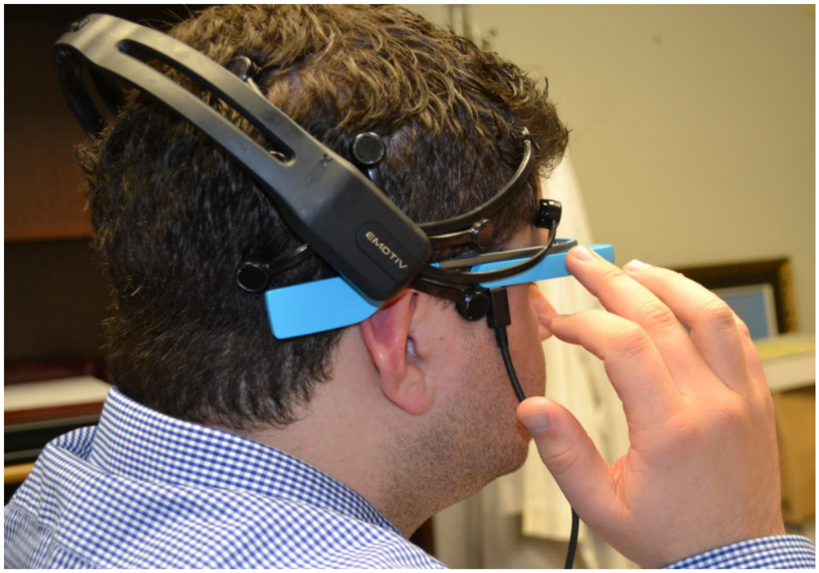


FIGURE 1: Participant wearing Google Glass and EmotivEpoc during the visual search experiment.

FIGURE 2: Participant taking the ATLS test during the patient vitals application simulation.

3.1 STIMULI

The system was designed based on Android Google Glass design guidelines (Google developers, 2015). The user interface design elements in the patient vitals simulation was developed after assessing and prioritizing the triage information by observing various patient monitoring tools in the trauma care department. Triage information was verified and evaluated by experts and the software was developed using Android Studio for Android version 19. The system design for the mobile interface was based on a flat navigation hierarchy with three levels of display as shown in Fig.4. The Navigation Design includes three different levels of information presentation.

a) Home screen: Home screen is the first screen users will see when launching the app.

b) Menu Page: Section Page is the second level of the app and represents the various applications in the device. Users need to select on the Patient Vitals app or the Visual Search task app depending on the experiment.
c) App page: Detail Pages are the third level of the Application. In the case of patient vitals application the details of each patient was presented. If any component has active criticality, the color of the component tile will change to yellow or red; yellow indicating low criticality and red indicating high criticality. The visual search task included presenting the first slide and the user navigating to the next screen by swiping or tapping.

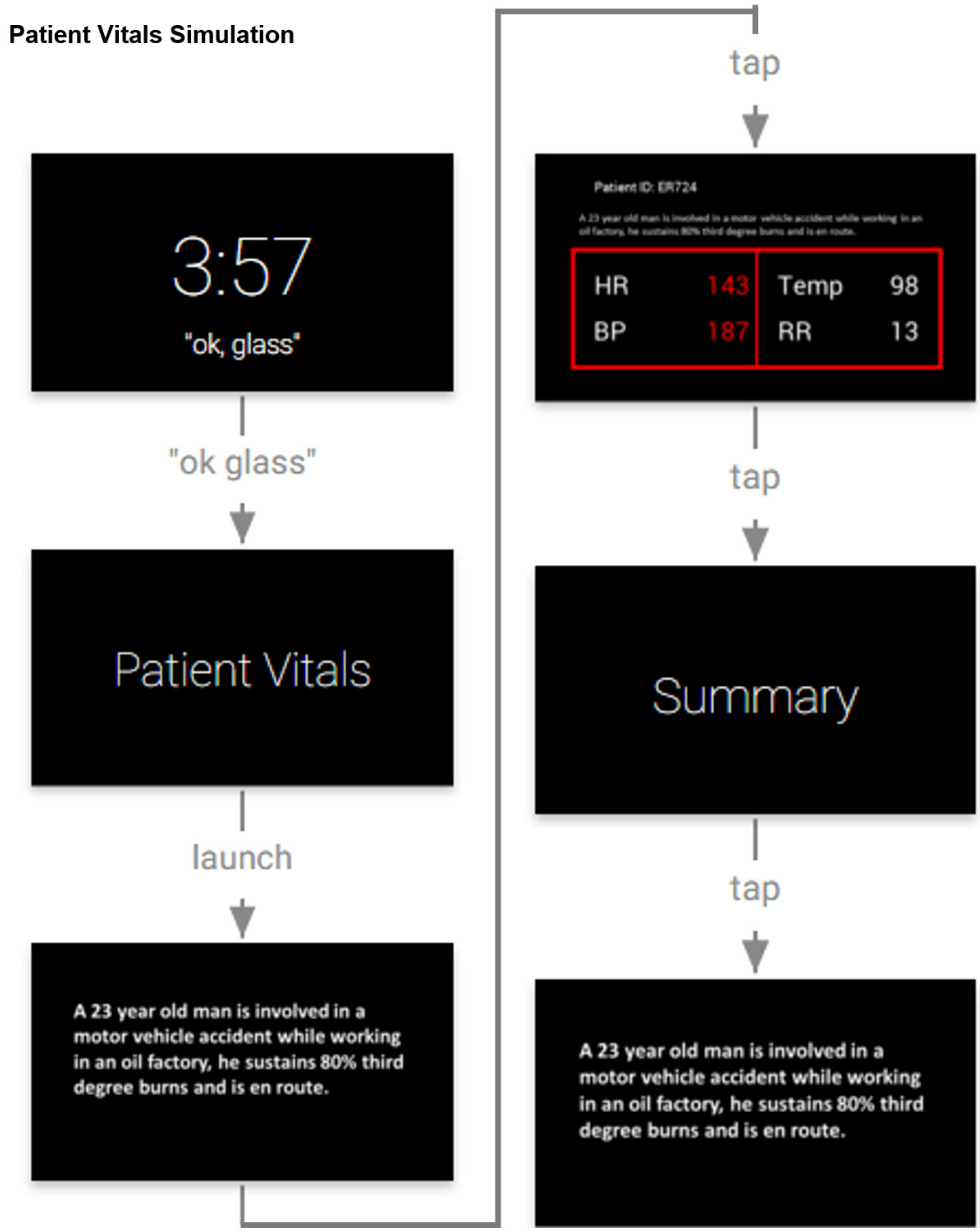


FIGURE 3: Navigation design of the Patient Vitals application.

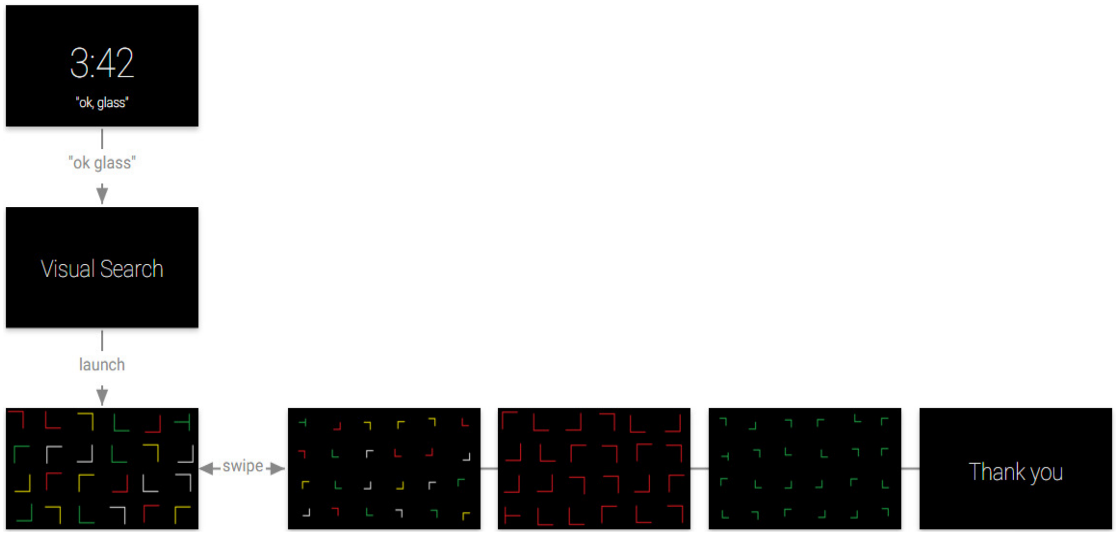


FIGURE 4: Navigation design of the Visual search task application.

3.2 Experimental Design and Procedures

Participants were introduced to the Google Glass device and were trained on the different gestures, which could be used to operate it, navigate between and within the applications. The training modules were untimed sessions and participants were encouraged to practice until they were familiar with the system. Familiarity was based on a subjective measurement of the participant's level of comfort in interacting with the interface and successful completion of a scenario similar to the testing scenarios.

3.2.1 Patient Vitals Simulation

The experiment conducted was a repeated measures design, with two within-subjects independent variables: type of User Interface (UI1 vs. UI2 vs. UI3) and frequency of data visualization (2 seconds vs. 6 seconds). The experiment was counterbalanced using Latin square with respect to the order of scenarios being tested and the type of system. Twelve different scenarios were tested to collect the appropriate metrics across the three different UIs and the two data visualization frequencies. All the scenarios involved monitoring the vital signs and user responses. All scenarios were presented with a summary for 8 seconds and patient vitals for 30 seconds. The scenarios were developed from observing emergency scenarios in Miami Valley hospital, Dayton and were evaluated by subject matter experts.

3.2.2 UI1

UI 1 consists of Patient ID at the top of the screen, below this the screen was divided into two halves, the left half contains the summary and the right half contains the three most important vital signs for the physician's evaluation.

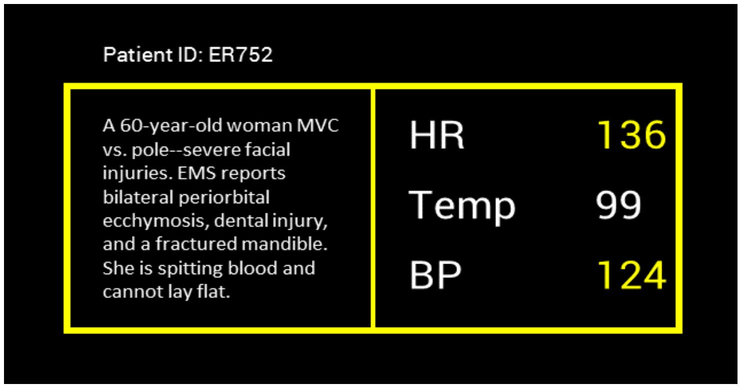


FIGURE 5: Screen layout of user interface 1.

3.2.3 UI2

UI 2 consists of Patient ID at the top of the screen followed by a summary, below this the screen is divided into two halves, the four most vital(Heart rate, BP, temperature and RR) patient information are presented in this area in a 2x2 matrix form.

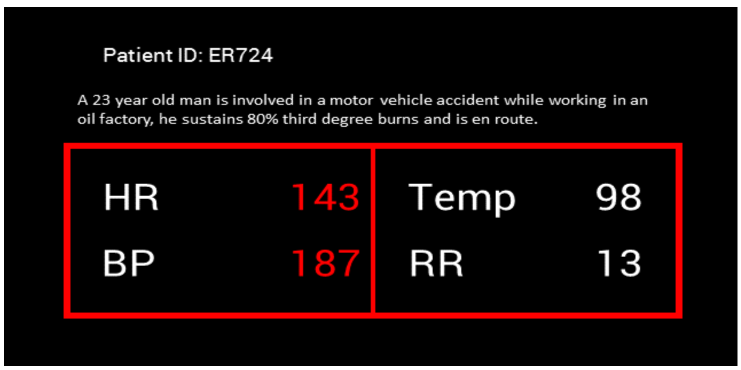


FIGURE 6: Screen layout of user interface 2.

3.2.4 UI3

UI 3 consists of Patient ID at the top of the screen, below this the screen is divided into two halves, the five most vital patient information (Heart rate, BP, spO2, temperature and RR) with age are presented in this area in a 3x2 matrix form.

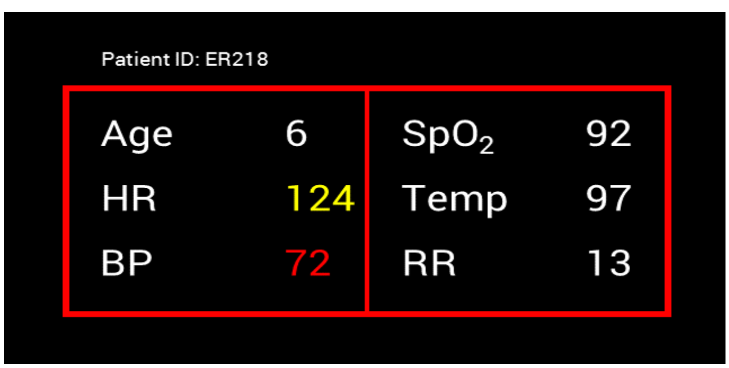


FIGURE7: Screen layout of user interface 3.

3.2.5 Visual Search Task

The experiment conducted was a repeated measures design, with four within-subjects independent variables: target and distractor color (Monochromatic vs. Polychromatic), size of the font (Large vs. Small), position of the target (Right half vs. Left half of the screen) and area in which the target is present (Inner vs. Outer area). The Google Glass screen displayed the target "T" shape in either of the two orientations; the top of the "T" shape faced either right or left. There were multiple "L" shapes as distractors in four different orientations; the top of the "L" shapes faced top, right, bottom, and left. Every slide had one target and 23 distractors in a 4 by 6 grid screen.

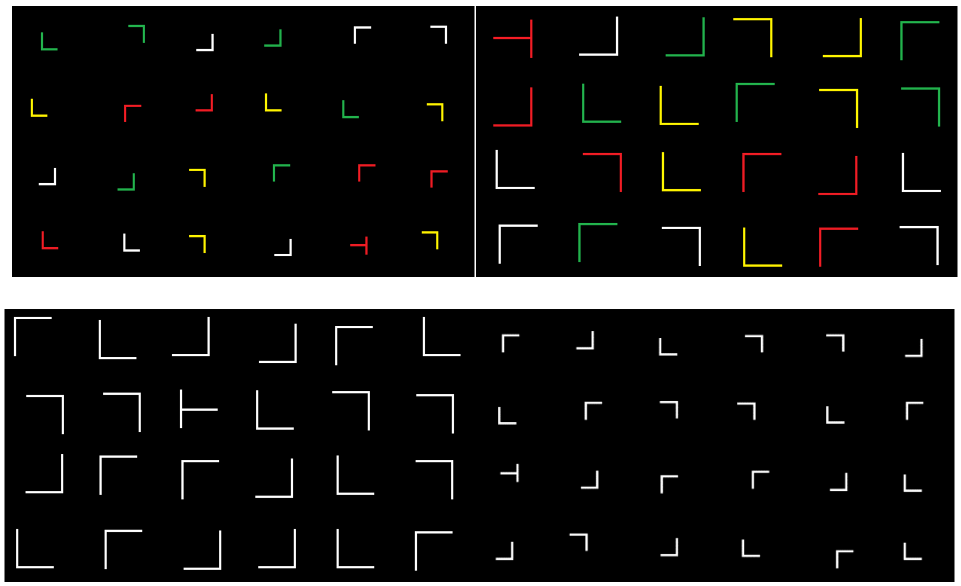


FIGURE 8: Types of screen layout for the visual search task with varying size, color, and target location: polychromatic small (Top left), polychromatic large (Top right), monochromatic large (Bottom left), monochromatic small (Bottom right).

3.3 Dependent Measures and Analysis

3.3.1 Patient Vitals Simulation

In order to evaluate the performance of the system several measures such as cognitive workload, ease of use, and performance times were collected. NASA TLX was used to measure the cognitive workload of the participants when performing a task and is an aggregate of six subscales: mental demand, physical demand, temporal demand, performance, effort and frustration (Hart &Staveland, 1988). Ease of use was measured using System Usability Scale (SUS) score. SUS provides a quick reliable tool to measure usability and learnability. It consists of a standardized ten item questionnaire with five response options. SUS was followed by a general questionnaire about the performance index of the device, application and the user interface. Performance time was measured using a stopwatch to measure the time taken by the participant to respond to each of the scenarios. This was calculated using the difference in the time taken by the participant to start writing their response and the time when the patient vitals scenario started. ATLS test response was collected to see the number of questions answered by the participants. This would help in evaluating the multitasking ability while using the augmented wearable device.

3.3.2 Visual Search Task

In order to evaluate the performance of the system a general questionnaire was used to evaluate the user interface design elements and the response time was collected using a stopwatch to measure the time taken by the participant to find the target in a particular slide. This was calculated using the difference between the time when the participant taps/swipes after finding the target from the current slide and the previous slide.

4. RESULTS

Results indicate that there was significant difference in the response time for doctors and residents (F (5,141), p-value < 0.001, ηp2= 0.031).There was no significant difference in response time for the different user interfaces and there was no interaction effect. Mean response time and standard deviation were 12.027 sec and 3.406 sec for doctors and 14.43 sec and 4.949 sec for residents. The mean response times with respect to the user interface were 13.6 sec for UI1, 13.31 sec for UI2 and 12.77 sec for UI3 with standard deviation of 4.59 sec, 4.34 sec and 4.31 sec respectively. When residents were further analyzed based on their experience, the response time was significantly different for Junior residents when compared to Senior residents and doctors (F (2,141), p-value < 0.001, ηp2= 0.211) Mean response time and standard deviation were 12.027 sec and 3.406 sec for doctors, 16.722 sec and 4.79 sec for junior residents and 12.139 sec and 3.994 sec for senior residents.

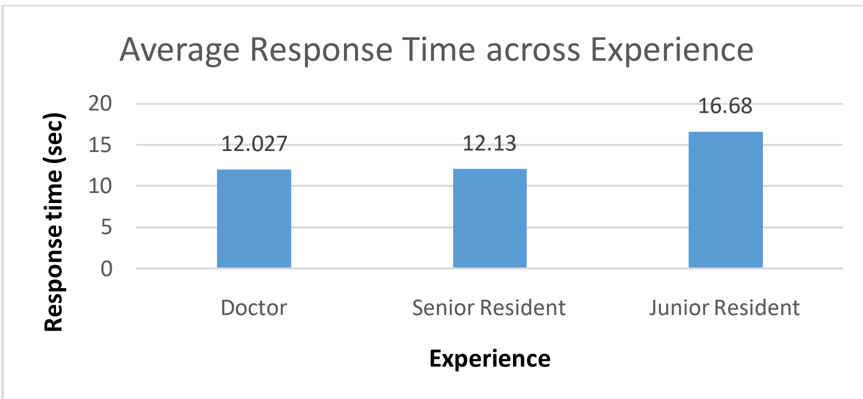


FIGURE 9: Average response time with respect to experience.

Analyzing the number of questions answered in the ATLS test, we found that there was no significant difference between doctors and residents in the number of questions answered. The mean number of questions answered was 4.5 by doctors, 3.67 by senior residents and 1 by junior residents.There was no significant difference in response time for the UI elements; color, size, left/right half of the screen and inner/ outer area of the screen, and there was no interaction effect.

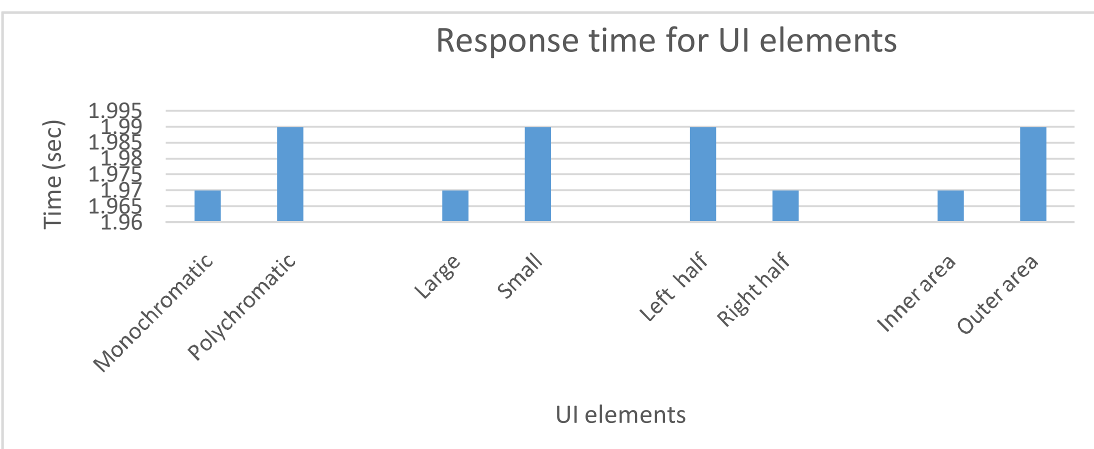
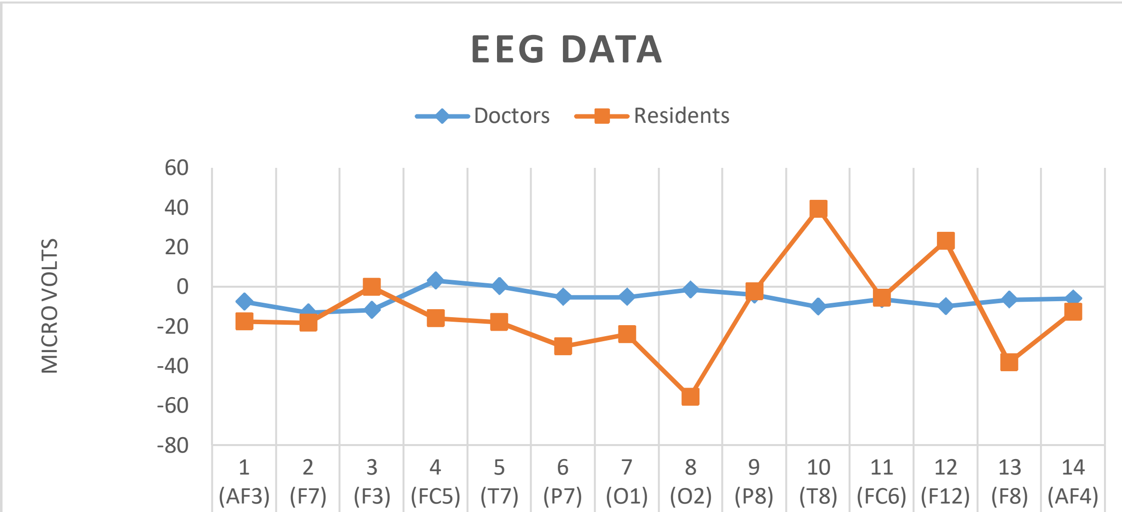


FIGURE 10: Response time for different UI elements.

The following chart shows the difference in brain signal amplitude averaged for doctors and residents in terms of microvolts. The table shows a comparison of these microvolt values against the respective channels.



	1 (AF3)	2 (F7)	3 (F3)	4 (FC5)	5 (T7)	6 (P7)	7 (O1)	8 (O2)	9 (P8)	10 (T8)	11 (FC6)	12 (F12)	13 (F8)	14 (AF4)
Doctors	-7.6	-13.	-11.	3.01	0.23	-5.1	-5.1	-1.5	-4.0	-10	-6.3	-9.9	-6.5	-6.1
Residents	-17.	-18.	-0.2	-16	-18	-30.	-24	-55.	-2.3	39.3	-5.5	23.0	-38.	-12.

FIGURE 11: Average electric data in microvolts against each EEG channel.

The EEG heat map, Figure 12 and 13, shows activity in the brain color coded ranging from red to blue, where the area marked in red is where the brain was most active and the area marked in blue is where it was least active. The figure shows that there were two areas of the brain that were most active for the visual search task. Figure 12 shows the brain activity of a participant whose temporal region of the brain was active. Figure 13 shows that there was more activity in both temporal and the frontal area of the brain.

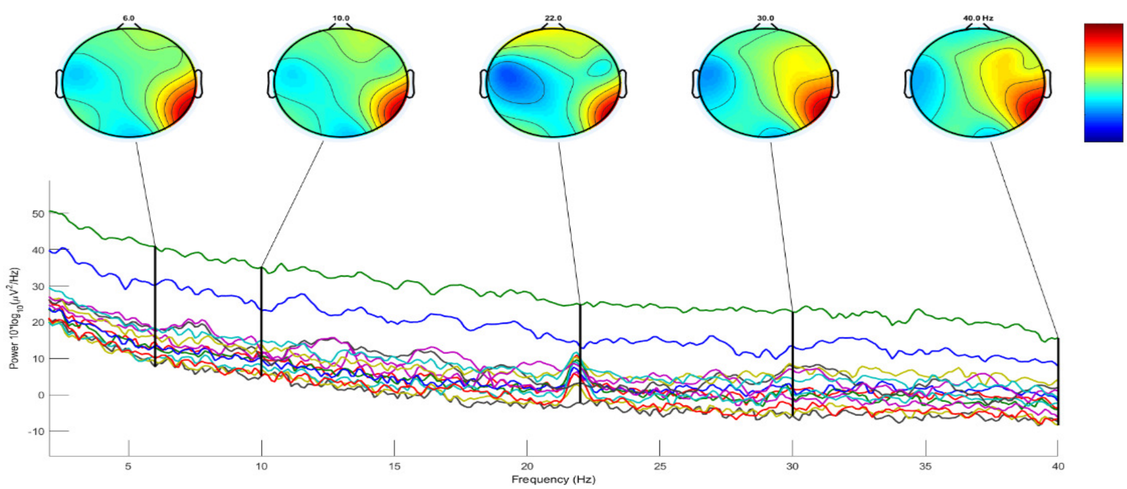


FIGURE 12: Heat map showing activity in the superior parietal cortex.

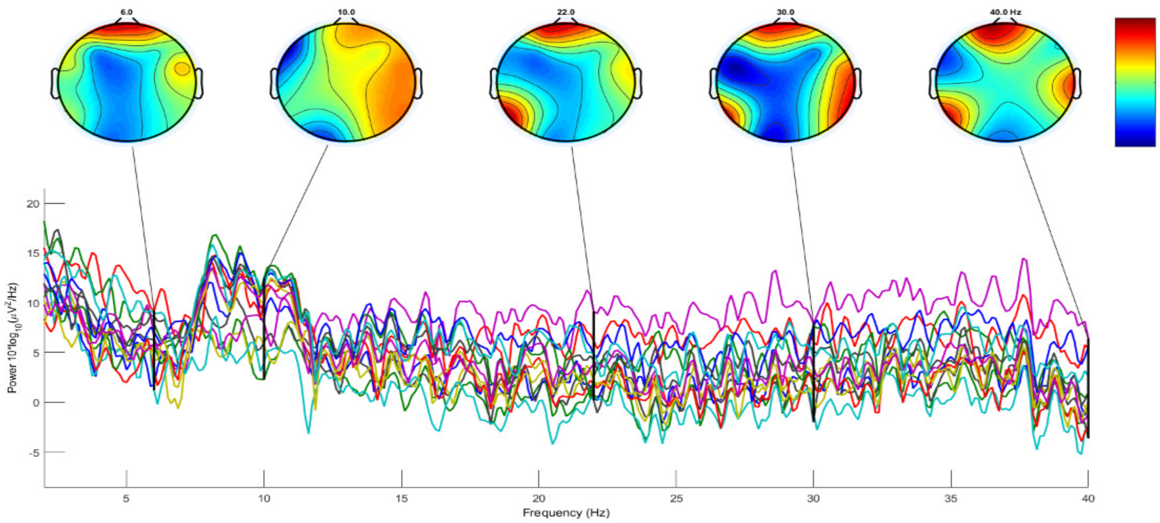


FIGURE 13: Heat map showing activity in the superior parietal and prefrontal cortex region.

User response for color, size, left/right position and inner/outer area of the screen did not have significant effect on the response time but experience had significant effect on the response time and there was no interaction effect (F(31,1131), p-value > 0.69, ηp2= 0.023). The mean response time for Doctors was 1.88 seconds per slide and for Residents was 2.08 seconds per slide with a standard deviation of 0.96 and 1.04 respectively.The NASA TLX mean score, given by Doctors was 42.93 and for Residents was 51.26 with standard deviation of 15.87 and 14.67 respectively.

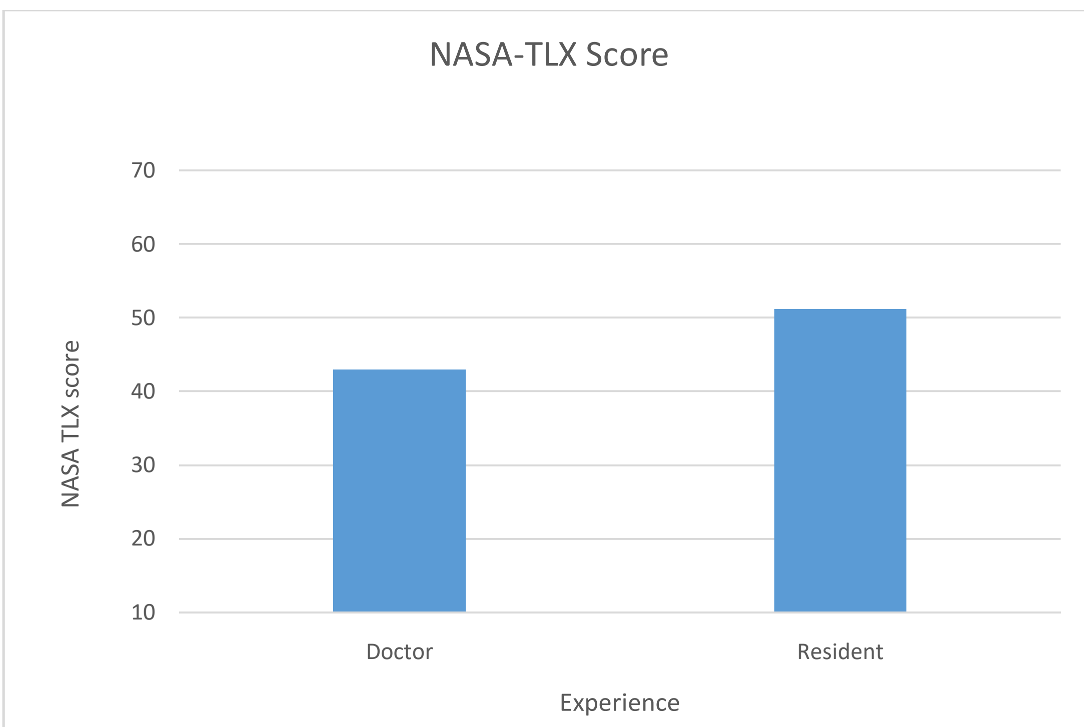


FIGURE 14: NASA TLX score across experience.

The following graph shows user preference response for color, size, left/right position, inner/outer area of the screen.

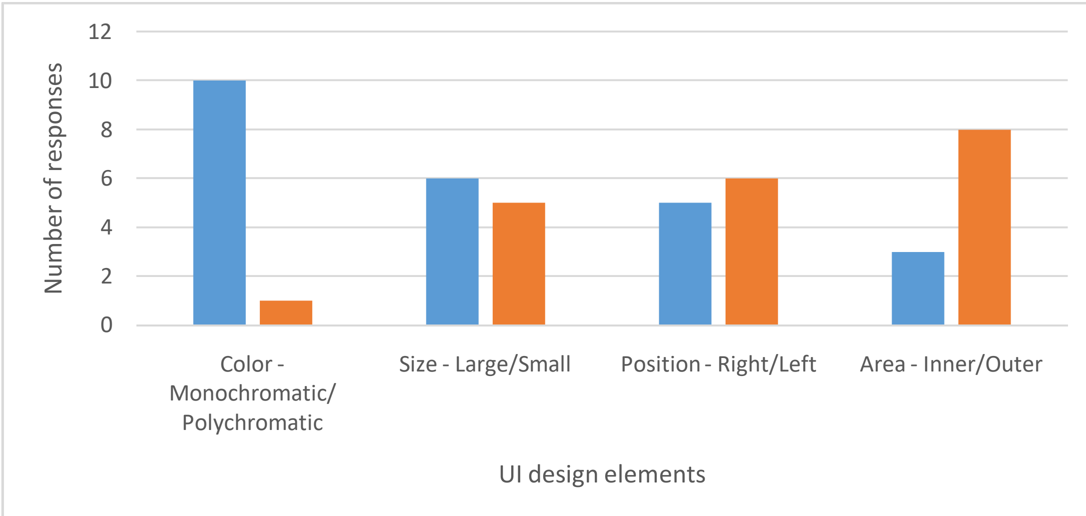


FIGURE 15: User response for preference of UI elements.

The System Usability Scale (SUS) results showed that there was no significant difference between the three User Interfaces. When compared between doctors and residents, there was no significant difference for UI1 and UI3, whereas for UI2 the SUS for junior residents was significantly lesser (F (2, 12), p-value = 0.0203, ηp2= 0.579) with mean and standard deviation values of 61.667 and 10.104 than senior residents and doctors with mean and standard deviation values of 77.5 and 4.33 and 72.5 and 3.16 respectively.

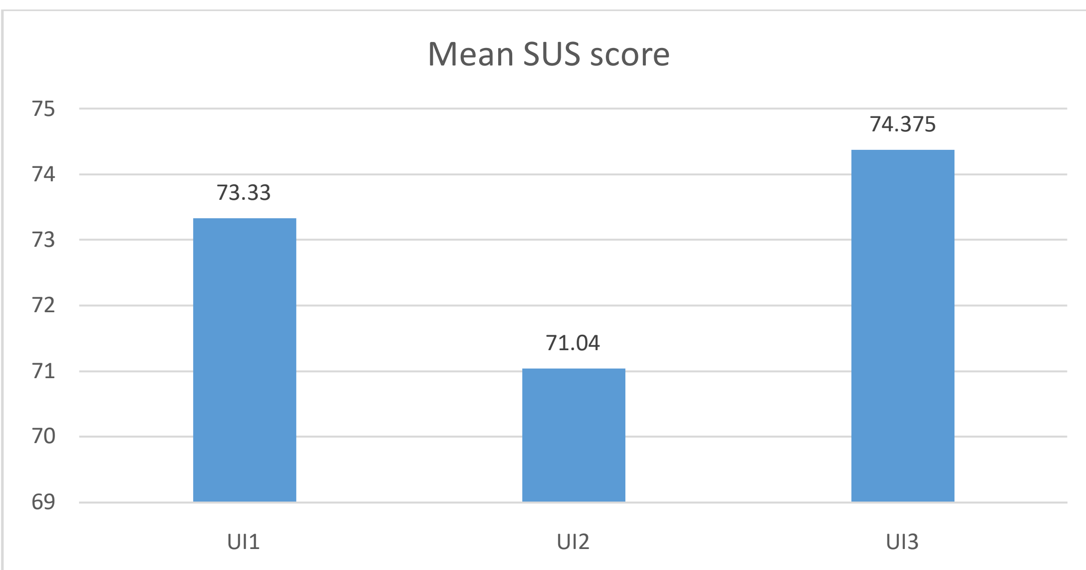


FIGURE 16: SUS scores for the 3 UIs.

The user response for the questionnaire was analyzed and the tables below show the average response for the questions in a scale of 1 through 5; where 1 is strongly disagree, 2 is disagree, 3 is neutral, 4 is agree and 5 is strongly agree.

#	Question	Response
1	Device Comfort	2.91
2	Application load time for the device	2.167
3	The use of heads-up display to improve patient monitoring and decision making	3.08
4	Device usefulness in trauma pre-hospital care	3.00

TABLE 2: User response for device.

#	Question	Response
1	Navigation through the application	3.667
2	Clarity and understandability of the application	3.833
3	Flexibility of the application	3.333
4	Application ease of use	3.75
5	Learnability of the application	4.167
6	Ability to accomplish task with the help of this application	3.41
7	Organization of information in the screen	3.75
8	Appropriate Content in the application	3.667

TABLE 3: User response for Patient Vitals application.

#	Question	Response		
		UI-1	UI-2	UI-3
1	Optimum number of elements within the screen across the 3 UIs	3.58	3.00	3.167
2	Design of screen layout across the 3 UIs	3.83	2.91	3.33

TABLE 4: User response for User Interface.

5. DISCUSSION

Upon analyzing the patient vitals simulation data it was found that junior residents took a longer time to process than when compared to senior residents and doctors. It is also evident from the ATLS test that the average number of questions answered was less compared to senior residents and doctors.

The user response shows that UI1 was comparatively better in the design of screen layout and the optimum number of elements than UI3 and UI2. The difference in the screen layout between UI1 and UI2 was the patient summary presentation which shows that the participants preferred the summary above the vital signs over no summary at all. The difference in the number of elements (Heart rate, blood pressure, temperature, etc.) in the screen is that UI1 has 4 and UI2 has 3. So, participants recognize that in the same screen space, when summary was presented UI1 had more information presented on the screen and it did not affect the attention levels compared to UI2.

For the visual search task it was found that there was no significant difference in size, color, right/left position and inner/outer area of the screen but the response time was significantly less for doctors than residents. However, the questionnaire results showed that monochromatic search was easier than polychromatic search, and additionally the targets in the outer area were easier to find when compared to targets in the inner area. This showed that participants visually scanned the outer area first and then the inner area.

The EEG data showed that there was more activity in the T8 channel area which included the temporal region as well as the temporal-parietal area and parietal area. Past research shows that the superior parietal lobe was associated with visual search. Hence the use of augmented devices for information presentation is useful for people such as surgeons who do multitasking during patient monitoring. Results indicate that participants experienced discomfort using the device and the application took less time to load. The users felt discomfort due to the heat generated when the Google Glass was used for a long time (greater than 30minutes); which included the learning phase before the experiment began. Future work should focus on evaluating other wearable form factors.

6. CONCLUSION

This study analyzed cognitive stress by using EEG and compared with the perceived cognition using NASA-TLX. By doing so this approach shows more insight into the trauma care physician's cognition. From the results, we can imply that wearable augmented display devices can enhance visualization for emergency response without additional mental workload and aid in decision making. Wearable augmented devices provide ubiquitous information especially in multitasking scenarios where users can have access to information on an "as needed" basis. The mean channel data shows that for residents the prefrontal area was active and all participants had temporal cortex active. This shows that the participants were not under high stress or in other words we can say that wearable augmented reality devices can aid human decision making during transfer of care. Understand the design of information presentation on the wearable augmented reality device to improve user experience and reduce cognitive workload. This study showed that there is no significant difference in the different screen layouts which can help design adaptive UI for emergency response. Adaptive UI shows relevant information based on the needs and creates less confusion to new users.Using NASA-TLX for the user's perceived cognition and at the same time comparing it with brain signals give research insight and help developers in designing future products. So future devices should use these evaluation techniques to move towards better usability.

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