IMPROVING TASK-SEVERITY AWARENESS IN INTENSIVE CARE UNITS

A Thesis

by

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Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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May 2019

Major Subject: Industrial Engineering

ABSTRACT

Intensive Care Units (ICUs) are complex socio-technical systems where interruptions can lead to medical errors. However, not all interruptions have a negative impact on patient safety. Most interruption mitigation strategies are reductionist in approach and may remove potentially important task- or patient-related information from the environment. In addition, mitigation techniques rarely involve technological interventions. In an effort to address this issue, a system called the Task-Severity Awareness Tool (TAT) was developed to make the severity of task-at-hand visible by enabling nurses to interact with several buttons during high-severity tasks to activate an awareness display (displaying "Do Not Disturb") that was located outside the ICU room. The TAT was effective at mitigating interruptions in the ICU environment, but it had several limitations including fixed actuators (i.e., buttons and foot pedals) and poor visibility (the LED display was located above the ICU door frame and could be easily missed). The objective of this research was to address the limitations of TAT and evaluate a novel Wireless Task-Severity Awareness Tool (WTAT). WTAT used wireless actuation using a smartwatch application and used an LED strip wrapped around the door frame to improve visibility. A study with 30 college students was carried out using the Tobii Pro Glasses 2 eye-tracker to evaluate the visibility of the WTAT compared to TAT. The results show that WTAT attracted a significantly larger number of fixations and visits. The findings of this study provide evidence for the efficacy of using LED strips for awareness displays to improve visibility. Future work is needed to evaluate if such improved visibility can help reduce unnecessary interruptions in the ICU.

DEDICATION

I dedicate this work to my parents and sister. I want you all to know that thanks to you I was able to pursue this endeavor. It was not easy, but it is done. Now, to move forward in life and start a new chapter.

ACKNOWLEDGMENTS

I would like to thank Dr. Sasangohar for guiding me every step of the way. I want you to know that you have done a great job. I am proud of having the opportunity of working with you. I also want to extend my gratitude to Dr. Ferris, who always cared about my well-being. Thank you for all the advice that you gave me. It definitely helped. It was a pleasure working with you. Additionally, I also want to thank Dr. Hamilton for giving me input and keeping me on track for doing my thesis. I really appreciate the opportunity of getting to know you. Another professor that always gave me advice was Dr. Don Smith. Dr. Smith, if you read this, I want you to know that your classes were excellent. Your experience complements these really well. You inspired me to grow inside an organization. I also want to thank my extended family from the Texas A&M Paintball Team. It was an honor playing with you and getting to know you all. So many good memories that served as an inspiration to work hard. Especially, in those days when I was not feeling well. I would like to thank Dr. Tashtoush and Dr. Khasawneh for making this lifelong dream possible. Thank you for the motivation. Finally, I want to thank my friends for being there for me when I needed it. There are a lot of you to mention but thank you, everyone. I would also like to acknowledge a couple of people from the ACE Lab that gave me advice throughout this research endeavor: James Flores, Vu Huong, Caro Rodriguez, Changwon Son, Larry Powell, Mahnoosh Sadeghi, and Arjun Rao. I want you all to know that I appreciate any time and effort you invested in giving me advice.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

My thesis committee consisting of Professor Farzan Sasangohar [Advisor] and Professor Thomas K. Ferris of the Department of Industrial and Systems Engineering and Professor Kirk Hamilton from the Department of Architecture, who supervised the work done for the thesis. The student worked independently on the thesis.

Funding Sources

I supported myself throughout my Master's program.

NOMENCLATURE

ICU	Intensive Care Unit
CVICU	Cardio Vascular Intensive Care Unit
TAT	Task-Severity Awareness Tool
WTAT	Wireless Task-Severity Awareness Tool
GPIO	General Purpose Inputs and Outputs
SBC	Single Board Computer
RPI 3	Raspberry Pi 3
TFF	Time to First Fixation
FC	Fixation Count
AOI FC	Area of Interest Fixation Count
AOI VC	Area of Interest Visit Count

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1. INTRODUCTION

Intensive Care Units (ICUs) are complex socio-technical systems that thrive on the interaction between staff, machines, and patients (Khon, Corrigan, & Donaldson, 2000). Unfortunately, ICUs can be an overwhelming environment to work in due to the complexity of tasks and environmental factors that can contribute to medical errors (Donchin & Seagull, 2002). Several complex tasks performed by doctors and nurses are vulnerable to errors, such as medication management (Carayon et al., 2014). A study found that 41.3% of errors occurred when administering medication, and 19.5% occurred during medical infusions (Flaatten & Hevrøy, 1999). Medication errors have been shown to deteriorate the quality of treatment that patients receive (Ferner & Aronson, 2000). Such errors occur due to several reasons, including high workload, fatigue, and interruptions (McGillis Hall et al., 2010).

Interruptions are frequent in ICU and may detract nurses from the primary task, affecting nurses' performance in the ICU (Drews, 2007). Research shows that nurses in general receive between 3.3 – 6.7 interruptions per hour (Biron, Loiselle, & Lavoie-Tremblay, 2009; Kosits & Jones, 2011).

These interruptions can result in a break in primary tasks, thus leading to an error. A study found that 28% of the interruptions were caused by patients, and 25% by other nurses (Kalisch & Aebersold, 2010). Another study found that 18% of interruptions caused by other nurses were due to non-work related reasons (Sasangohar, Donmez, Easty, Storey, & Trbovich, 2014).

Interruptions increase the probability of procedural failures (e.g., not using the medication administration chart, not reading medication label) and clinical errors (e.g., incorrect dosage, strength, medication) (Westbrook, Woods, Rob, Dunsmuir, & Day, 2010). Negative interruptions should be kept to a minimum and nurses should not be distracted from their primary task for extended amounts of time due to task degradation (Grundgeiger, Sanderson, MacDougall, & Venkatesh, 2010). However, not all interruptions have a negative impact on the patient (Sasangohar, Donmez, Trbovich, & Easty, 2012). Interruptions can convey important information that may be beneficial for the overall patient outcome. These can range from advising a new treatment, using alarms to inform nurses of patients' status, or when a nurse is interrupted to avoid an error (Grundgeiger & Sanderson, 2009).

Current interventions include solutions such as interruption vests (Bennett, Dawoud, & Maben, 2010), trying to make changes in the workplace culture (Jain, Miller, Belt, King, & Berwick, 2006), and red tape on the floor to create a no interruption zone around the medicine preparation area (Anthony, Wiencek, Bauer, Daly, & Anthony, 2010). However, such methods are reductionist in approach and may remove potentially important task- and patient-related information from the environment. In addition, these techniques rarely involve technological interventions.

To address this gap, Sasangohar et al. (2015) designed the Task-Severity Awareness Tool (TAT) to reduce only the unnecessary interruptions nurses experienced in the Cardiovascular Intensive Care Unit (CVICU). This tool consisted of an LED scrolling display, an Arduino Uno microcontroller, two buttons, and one foot pedal. This tool

worked by having the Arduino Uno activate the display when it detected interaction with either the buttons or the foot pedal. When the display was active, a “Do not disturb” message was displayed to prevent interruptions when a high-severity task was carried out. The findings from this research suggest that the use of awareness displays in the ICU was beneficial to nurses and patients overall. In particular, TAT decreased the number of unnecessary interruptions significantly (Sasangohar et al., 2015).

Even though this tool improved the working environment in the ICU, some limitations of the study needed to be addressed. For example, nurses would forget to completely interact with the tool (Sasangohar et al., 2015). In addition, interaction with the fixed position actuators (i.e., buttons and foot pedal) required additional movement which was inconvenient (e.g., during procedures). Furthermore, the location of the display (top of the ICU door frame) was deemed problematic since it might fall outside the field of vision in heads down or movement between adjacent rooms (both of which are typical scenarios in ICUs) (Sasangohar et al., 2015).

This research addresses some of these limitations by designing a new version of the TAT that uses more convenient wearable actuators as well as a new display design with improved visibility. A lab experiment was conducted to compare the TAT’s display against the new design. In addition, it is expected that a new display that covers more area would have a higher probability of being noticed and does not necessarily have to be within the focal sight line of a person.

1.1. Problem Statement

The TAT was proven to reduce interruptions nurses' experience in the ICU. However, it had several limitations. First, having static actuators was troublesome for nurses. A method of improving nurse interaction with the actuators is needed. Second, the display's noticeability was deemed low due to the location. A new display is needed in order to improve the noticeability of the display and raise awareness to people that interact with the display (Lee, Wickens, Liu, & Boyle, 2017). A new tool was built to address these limitations.

2. DESIGN OF WIRELESS TAT (WTAT)

2.1. Design of WTAT - Tool Redesign for Ease of Use

Microcontroller and single board computer (SBC) technologies show promise in addressing the technological limitations of the TAT. Such technologies are known to be inexpensive, have the capability to interact with different tools and sensors and show promise in integrating a large number of technological tools that are tailored to specific functions (Rodriguez-Paras & Sasangohar, 2017). For example, a tool to monitor blood glucose and adjust insulin levels to keep the patient stable (Surywanshi & Chougule, 2017) or a tool to continuously monitor patients' vitals remotely (Patil & Hogade, 2012). While TAT used a microcontroller called Arduino Uno, capabilities of other microcontrollers and SBCs should be investigated to understand opportunities for improvement. As the first step to improve TAT, I conducted an analysis comparing Arduino Uno with Raspberry Pi 3 (RPI 3), a dominant SBC. The parallel comparison of the two technologies was carried out to evaluate their capabilities across several criteria such as connectivity, input/output, price, and computing power (Table 1).

Table 1: Parallel comparison of technology (Arduino Uno and Raspberry Pi 3)

Criteria	Arduino Uno	RPI 3
Analog Input	6 analog pins	Needs add on
Digital Input/Output Pins and PWM Outputs	14 digital I/O pins	40 GPIO Pins
Storage	32 KB flash memory	micro SD card
Processor	ATmega328P	Quad-Core ARMv8
CPU Speed	16 MHz	1.4 GHz
USB Ports	1	4
Price	$24.95	$39.95
Connectivity	Requires additional components for Bluetooth, Wi-Fi, IR, and RF	Bluetooth and Wi-Fi connectivity included. Attachments for IR or RF needed
Citation	(Durfee, 2011)	(Magpi, 2018)

In order to make the new tool wireless, several criteria were considered necessary. The specifications of the technology were compared based on what was considered to be needed in order to establish a wireless actuator connection. A decision matrix was used to rank and quantify which type of technology was more suitable (Table 2). This was done by having a student coder subjectively rate each criterion. The ranking was then discussed with a second coder (research advisor) to validate the selection. This analysis showed that the RPI 3 had better utility for this project. Therefore, RPI 3 was chosen as an SBC for redesigned TAT.

2.2. Design of WTAT – Hardware Design

The Wireless Task-Severity Awareness Tool (WTAT) incorporated the use of a smartwatch as a wireless wearable actuator, which connects via Bluetooth to a RPI 3, an

SBC, which uses the general-purpose input/output (GPIO) pins to control a relay. The RPI 3 was connected by three input cables: ground to close the circuit and have the current flow; 5 volts required by the relay to operate, and signal cable to transmit a voltage to activate/deactivate the relay. The power adaptor of the display is connected to the output of the relay. When the RPI 3 activates the GPIO pin, it activates the relay and allows for current to flow, thus powering the display. See Figure 1 for a WTAT's system schematics. If the GPIO pin is disengaged, it proceeds to deactivate the relay and interrupt the current flow, thus powering off the display. See Figure 2 for the WTAT hardware setup.

Table 2: Decision matrix scale used: 0 to 5, with 5 being the best

Criteria	Arduino Uno	RPI 3
Analog Input	3	1
Digital Input/Output pins	2	3
Storage	2	4
Processor	3	5
CPU Speed	3	5
USB Ports	0	5
Price	5	4
Connectivity	2	4
Total	20	31

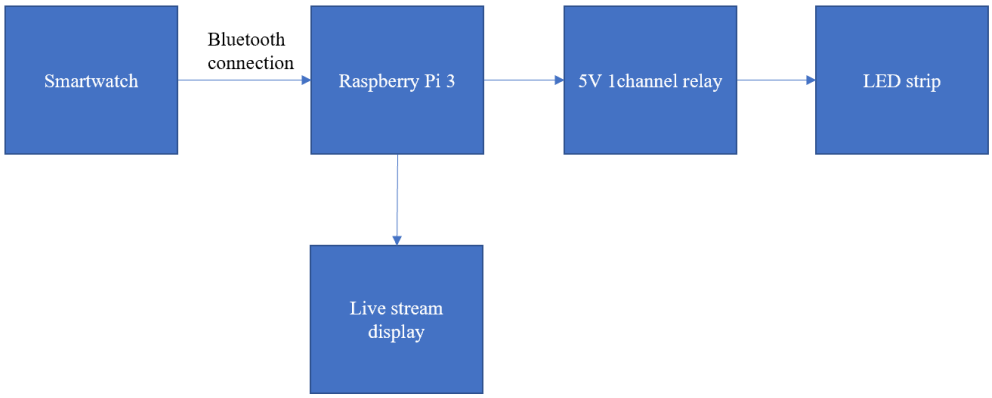

Figure 1: WTAT System's schematics

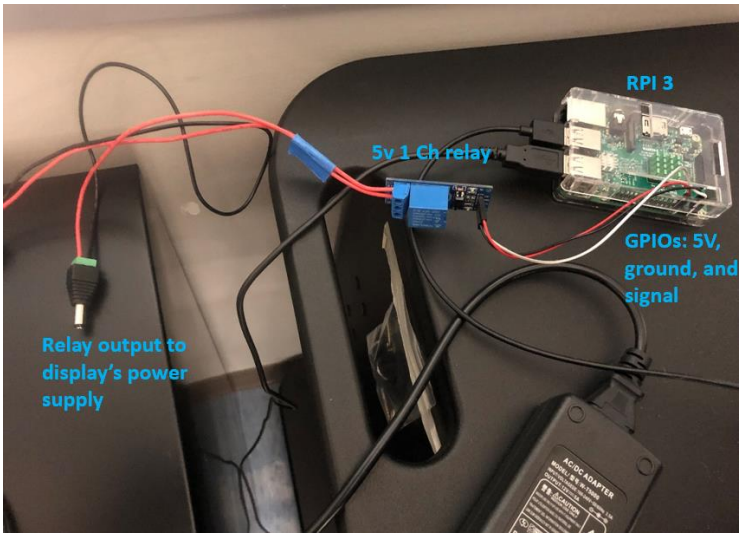

Figure 2: WTAT hardware setup (RPI 3 and relay)

2.3. Design of WTAT – Software Design

The actuator design is part of the Smart Nursing System which is a smartwatch app that incorporates the use of the WTAT. The smartwatch that acts as a wearable wireless

actuator has an app that was designed. The Smart Nursing System app allows for the user to activate the WTAT, set up alarms, collect biofeedback from the nurse, and if the smartwatch permits, record and listen to voice notes.

A RPI 3 script was developed in Python to enable wireless integration of WTAT features (see Appendix A for the software design). When system powers up it initializes the integrated Bluetooth module in the RPI 3 to continuously search for known devices (e.g., smartwatch actuators). Bluetooth was preferred due to its connectivity range. In order to help nurses that may leave the ICU room, the RPI 3 will automatically connect with the smartwatch and begin to accept data the incoming data from the smartwatch. The current accepted transmitted data is the status of the display, heart rate, and time, which offers a continuous monitoring tool for providers' well-being. This data is received about every second.

If the received data contains a command to activate the display, the RPI 3 will proceed to activate the GPIO pin where the relay that controls the display is connected. The display will remain active until an 'Off' command is received, which will disengage the GPIO pin.

The RPI 3 remains active when disconnected from the smartwatch so that automatic reconnection is achieved. In such cases, the system will stop displaying the streamed data and will start searching for a known smartwatch. This design eliminates the need for user interaction with the system anytime they leave the ICU room or go outside the Bluetooth range. As soon as the RPI 3 connects to a known smartwatch that it is in

range, it will start receiving data from the smartwatch and allowing the smartwatch to control the display.

2.4. Design of WTAT – Display Design

The TAT used an LED scrolling display which can display and communicate words and symbols (Figure 3). However, the message needed to be perceived and understood to ensure proper change in behavior. This may impose a challenge since 1) potentially illiterate users may not understand the message, and 2) hospital personnel or visitors new to the ICU unit may not understand what the message conveys. In addition, TAT seemed to be located on the edge of the peripheral vision from a normal line of sight. Not having a normal line of sight when walking (head down) will most likely situate the display outside of the vertical visual limit of the eye, which is about 50° (Lee et al., 2017; Torrejon, Callaghan, & Hagras, 2013).

Figure 3: TAT's display in a simulated lab setting

To improve these limitations from the TAT, several display alternatives were considered (e.g., holographic technology, laser technology, creating our own type of display). However, for this first phase of the project, the intention was to be able to develop the tool with over-the-counter items that are low in cost and readily available. Therefore, the alternative will be an LED strip which was compared with the TAT's design which incorporated an LED scrolling display.

WTAT incorporated a novel design using an LED strip wrapped around the door frame (Figure 4). With this design, the field of view has a larger width than height, so this display maximizes the probability of it being in the field of vision (Torrejon et al., 2013). In addition, the LED strip in this new design covers more area, so it is expected to be more effective at capturing attention when it is not directly in the normal line of sight of a

person. Also, there is a higher probability of the display entering the foveal field of vision where the probability of distinguishing color is higher (Hansen, Pracejus, & Gegenfurtner, 2009; Lee et al., 2017). Since this display design does not portray words or symbols, any users regardless of literacy can perceive it as an emergent feature. However, similar to TAT, users have to be trained to understand what it means to have the display on. Next chapter documents a lab study comparing the visibility of TAT and WTAT.

Figure 4: WTAT's LED strip wrapped around the door frame

3. WTAT EVALUATION STUDY

3.1. Study Design

A study was designed to evaluate the improvements made to TAT by comparing the visibility of TAT and WTAT. To assess visibility, an eye-tracking device, Tobii Pro Glasses 2 (Figure 5) was used to measure two dependent variables: Area of Interest Visit Count (AOI VC), which is the amount of times gaze enters an AOI and Area of Interest Fixation Count (AOI FC) which is the amount of times a fixation occurs inside an AOI (Ares et al., 2013). The independent variable was the display type: either TAT (LED scrolling display that when active displays “Do not disturb”) or WTAT (LED strip that turned on when activated). The study was a within-subjects design and conditions were counterbalanced to reduce the effects of the learning curve that can influence the results. A post-study interview was conducted to collect participants’ opinion when it comes to the effectiveness of the displays. The study received approval from Texas A&M University’s Institutional Review Board (IRB#: IRB2018-0697D).

Figure 5: Tobii Pro Glasses 2

3.2. Apparatus

In addition to the eye-tracking device, this study required the following items:

- Tablet with Tobii Pro Controller was used to control the Tobii Pro Glasses 2
- A phone with two checklists was used by the participants throughout both conditions
- The light meter LM-50KL was used to assess illuminance from a fixed distance
- Voice recorder to record the interviews with the participants
- Tobii Pro Labs for video coding and extract the data into a spreadsheet

3.3. Participants

Thirty participants (16 males, 14 females; mean age = 27.4 years, standard deviation = 8.84 years) were recruited from the Industrial and Systems Engineering Department at Texas A&M University via an email that was sent to the graduate and undergraduate student listserv. See Appendix B for the recruitment email. Overall, 20

graduate and 9 undergraduate students participated. In addition to current students, one recent school graduate participated in the study.

3.4. Procedure

Participants completed two conditions that follow the same course of action (leaving Emerging Technologies Building lab room 2024 and entering Emerging Technologies Building lab room 2023). However, the only difference between conditions was the active display that participants encountered. The door locations created a 90° angle which replicates a possible condition when nurses are going from door to door.

Participants arrived at our research lab (Applied Cognitive Ergonomics Lab at Texas A&M University) where they were asked to read and sign the consent form (Appendix C). Participants then completed a background questionnaire (Appendix D) which documented some basic information (e.g., participant's gender, age, classification (graduate, undergraduate, professional)) in order to assess any similarities between participants. After the background questionnaire was completed, the eye-tracking device (Tobii Pro Glasses 2) was introduced. Participants were asked to assume the role of an ICU nurse and were deceived into believing that the study's objective was to use eye-tracking to compare two alternative sets of instructions for patient care. The participants were asked to wear the glasses and were guided through the calibration process, which involved having the participant staring at a bullseye target for 3-5 seconds. After successful calibration, the participant was asked to exit the lab and enter an adjacent room to check up on their patient while reading a checklist on a smartphone device. See Figure 6 for a visual representation

of the conditions that participants experienced. Refer to Appendix E for the checklist examples. The adjacent room's door was equipped with both TAT and WTAT, and depending on the condition only one was turned on. Participants were not given any information about these displays.

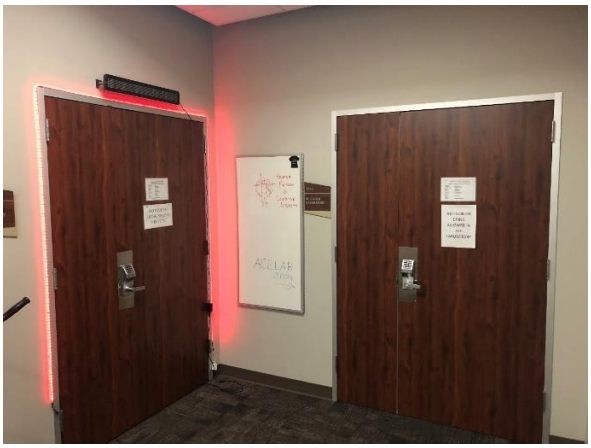

Figure 6: Visual representation of the conditions that participants experienced

Before exiting the first room, participants were asked to signal the researcher when they were ready to begin to study and the researcher would start recording the eye-tracker video. At this point, the researcher opened the door for the participant to exit the first room. The researcher stepped aside and followed the participants to the adjacent room. Participants were then asked to open the door to the adjacent room, enter, and pretend to check on their patient. After approximately 15 seconds in the room, participants were asked to return to the first room. The researcher switched the condition (display) and prompted the participant to try a different checklist on the phone, and repeat the same

process. After the completion of both scenarios, the participants were debriefed on the real objective, which was to evaluate the two displays and not the information that was being presented to them on the phone screen. Refer to Appendix F for an explanation of what was said during the debriefing process. If the participant did not have questions, the participant was asked to consent to participate in the interview portion verbally. The questions were in relevance to the displays (e.g., to see if these were noticed, and which one is preferred). Refer to Appendix G to observe the exit interview questions. After the interview, the participants received a $10.00 compensation, and the participant signed the cash log sheet. The entire study took approximately 20 minutes to complete.

3.4.1. Displays' Illuminance and Luminous Intensity

The illuminance of the two displays was measured in foot-candles (fc) using a light meter LM-50KL to assess potential large differences. The measurements were taken from 221.3 cm away at a height of 170 cm. The middle portion of the highest part of the displays was used as reference points (Figure 7). Luminous intensity was then calculated using Lambert's Cosine Law. The following variables were used to solve for luminous intensity: angle of incidence, distance from display to eye-level height, and illuminance (Figure 8). Refer to Table 3 for illuminance measurement and luminous intensity results.

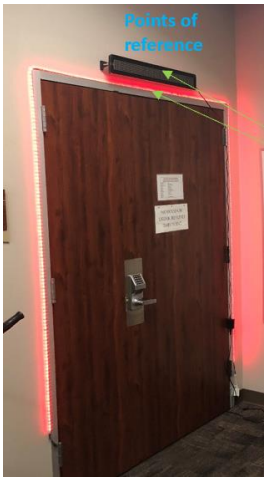

Figure 7: Points of reference for measuring illuminance and calculating luminous intensity for each display

It can be concluded that at an eye-level of 170 cm and 221.3 cm away the WTAT's display was emitting more light than the TAT's display. The observers' eyes received more illuminance from the WTAT's display than the TAT's display. Additionally, the WTAT's display emitted more visible light per solid angle than the TAT's display.

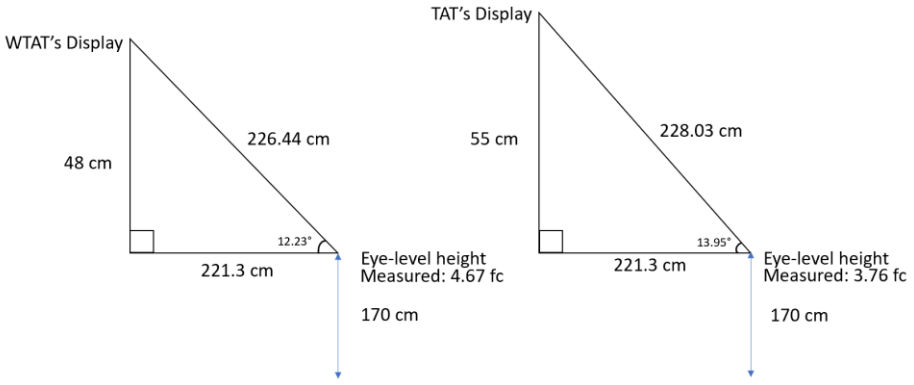

Figure 8: Layout for illuminance measurements and luminous intensity calculations

Table 3: Illuminance measurements and luminous intensity results for the displays

Display Type	Eye height (standing) (cm)	Environment's illuminance (fc)	Illuminance measured at eye-level height (fc)	Angle of incidence (deg)	Luminous intensity (cd)
WTAT	170 cm	7.28 fc	4.67 fc	12.23°	24.406 cd
TAT	170 cm	7.28 fc	3.76 fc	13.95°	20.139 cd

3.4.2. Data Extraction Process

The software used to extract the AOI FC, and AOI VC was the Tobii Pro Lab Version 1.102.16417 (Figure 9). This software allowed the researcher to upload photos of the door frame and select each display as different areas of interest within these pictures. The software had a function to run an automatic mapping of the gaze onto the areas of interest. While the automated mapping shows promise, it was observed that the process did not capture all gazes so manual fine-tuning was conducted on a selected portion of the videos frame by frame to ensure that the gaze point was in the appropriate part of the snapshot. Recorded video was analyzed from the time participants exited the first room until they were inside the adjacent room.

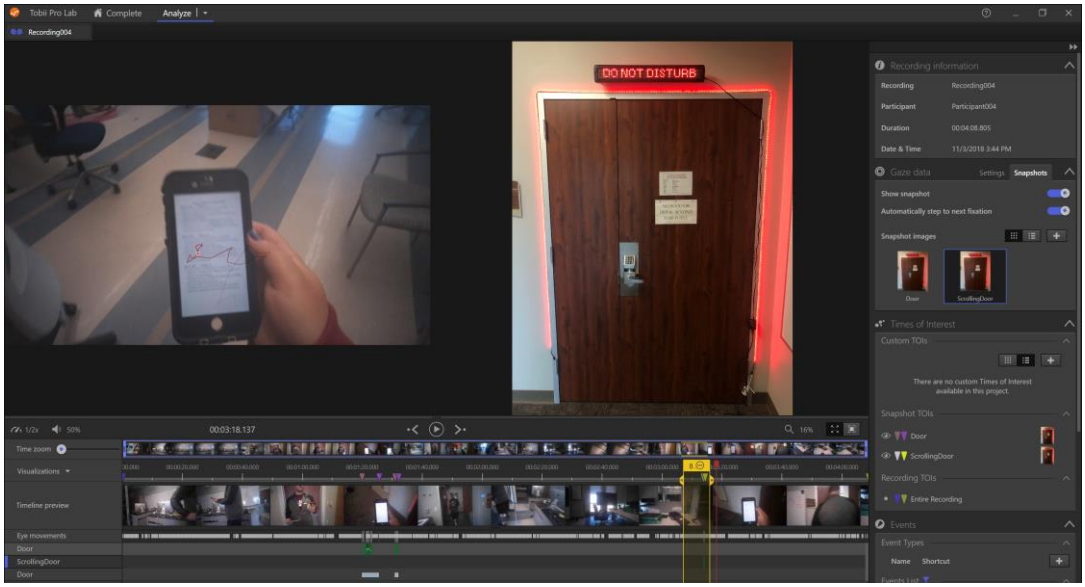

Figure 9: Tobii Pro Lab version 1.102.16417. Left side is actual video footage, and the right side is the snapshot used to map the gaze points, adapted from (Tobii AB, 2019)

Per Tobii Pro Lab recommendations, an attention filter was used since there are some dynamic components in the study (e.g., participant movement and screen movement), and this attention filter increases the velocity threshold parameter in order to make sure that the fixations are not just rapid movements caused by the body moving (Tobii AB, 2019). See Figure 10 for the settings on the attention filter.

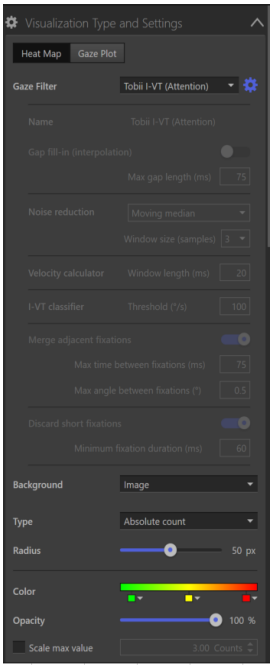

Figure 10: Attention filter settings, adapted from (Tobii AB, 2019)

3.4.3. Data Coding

Pictures of the displays were used to assess fixations in the areas of interest within Tobii Pro Labs. Figure 11 shows how the display area for the LED strip and the LED scrolling display were divided. Display detection can occur outside of the foveal vision, so wider areas of interest were drawn to account for participants noticing the displays while not fixating directly into these (Hansen et al., 2009; Torrejon et al., 2013).

Figure 11: Areas of Interest WTAT's display (left side) and Areas of Interest TAT's display (right side), adapted from (Tobii AB, 2019)

3.5. Results and Discussion

In total, 30 participants performed the study. There were 16 males and 14 females with an average age of 27.4 with a standard deviation of 8.84 years. In total, there were 20 graduate students, 9 undergraduate students, and 1 professional. Nineteen out of 30 participants claimed to wear glasses. None of the participants reported using medication that could affect their attention, three mentioned having problems with their peripheral vision, and only 1 participant was affected by colorblindness.

3.5.1. Results for Fixation Counts (FC)

An analysis of variance (ANOVA) was conducted using JASP 0.9.0.1 to determine which display was more effective at attracting the attention of the participants. As shown in Table 4 display type had a significant effect on the number of fixations ($F(1,55) = 9.201$, $p = .004$). As shown in Figure 12, WTAT had a significantly higher fixation count compared to TAT.

As shown in Table 5 and Table 6, the doorknob fixations were compared with the displays used in the study (WTAT and TAT). There was not a significant difference in the AOI FC between the WTAT (61) and the doorknob (48), ($F(1,56) = 0.4909$, $p = 0.525$), but there was a significant difference between the TAT (3) and the doorknob (57), ($F(1,54) = 32.83$, $p < .001$). Overall, the WTAT had a significantly larger number of fixations (61) when compared to the doorknob (48) and the TAT (3).

Table 4: ANOVA results for AOI FC WTAT and TAT

ANOVA – AOI FC

Cases	Sum of Squares	df	Mean Square	F	p
WTAT = 1, TAT = 2	56.77	1	56.772	9.201	0.004
Residual	339.37	55	6.170		

Note. Type III Sum of Squares

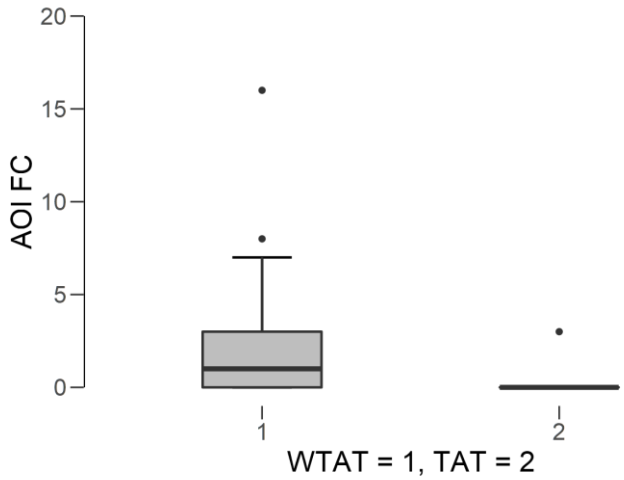

Figure 12: Boxplot comparison of fixation count between WTAT and TAT within the area of interest

Table 5: ANOVA results for AOI FC WTAT and doorknob

ANOVA - AOI FC WTAT Control

Cases	Sum of Squares	df	Mean Square	F	p
WTAT = 1, Doorknob = 2	2.914	1	2.914	0.409	0.525
Residual	399.241	56	7.129		

Note. Type III Sum of Squares

Table 6: ANOVA results for AOI FC TAT and doorknob

ANOVA - AOI FC TAT Control

Cases	Sum of Squares	df	Mean Square	F	p
TAT = 1, Doorknob = 2	52.07	1	52.071	32.83	< .001
Residual	85.64	54	1.586		

Note. Type III Sum of Squares

Additionally, the variables gathered from the demographic survey were used as covariates in an ANCOVA analysis. It was found that age and gender did not have a

significant effect on the AOI FC. See Appendix H for the different ANCOVA tables. For classification, the use of prescription glasses, issues with peripheral vision, and color blindness as covariates, participants were not evenly affected by these conditions to obtain accurate results. Not a single participant reported using medication that affects attention, so it was not possible to observe if this covariate could impact the results.

3.5.2. Results for Visit Counts (VC)

An ANOVA was conducted to determine which display had more visits in the areas of interest. As shown in Table 7, the results show that display type had a significant effect on the number of visits ($F(1,55) = 12.61$, $p < .001$). As shown in Figure 13, WTAT had a significantly higher visit count compared to TAT.

Table 7: ANOVA results for AOI VC WTAT and TAT

ANOVA - AOI VC

Cases	Sum of Squares	df	Mean Square	F	p
WTAT = 1, TAT = 2	27.05	1	27.054	12.61	< .001
Residual	118.00	55	2.145		

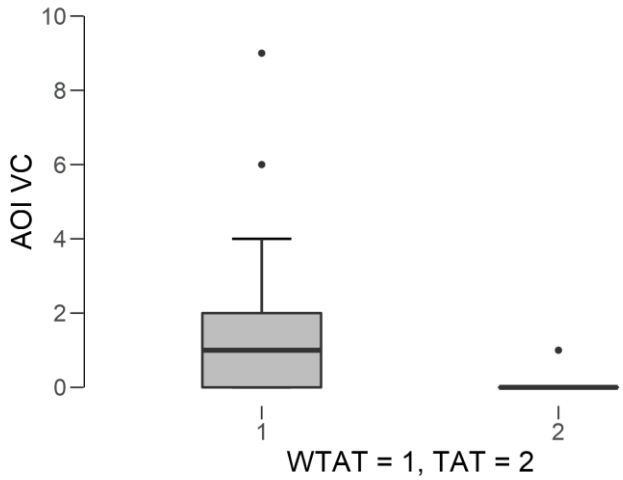

Figure 13: Boxplot comparison of visit count between WTAT and TAT within the area of interest

As shown in Table 8 and Table 9, the doorknob visits were compared to the displays used in the study (WTAT and TAT). There was not a significant difference in the AOI VC between the WTAT (41) and the doorknob (30), ($F(1,56) = 0.859$, $p = 0.358$), but there was a significant difference between the TAT (1) and the doorknob (31), ($F(1,54) = 74.54$, $p < .001$). The WTAT had a significantly larger number of visits (41) when compared to both the doorknob (30) and the TAT (1).

Table 8: ANOVA results for AOI VC WTAT and doorknob

ANOVA - AOI VC WTAT Control

Cases	Sum of Squares	df	Mean Square	F	p
WTAT = 1, Doorknob = 2	2.086	1	2.086	0.859	0.358
Residual	136.000	56	2.429		

Note. Type III Sum of Squares

Table 9: ANOVA results for AOI VC TAT and doorknob

ANOVA - AOI VC TAT Control

Cases	Sum of Squares	df	Mean Square	F	p
TAT = 1, Doorknob = 2	16.07	1	16.071	74.54	< .001
Residual	11.64	54	0.216		

Note. Type III Sum of Squares

Additionally, the variables gathered from the demographic survey were used as covariates in an ANCOVA analysis. It was found that age and gender did not have a significant effect on the AOI VC. See Appendix I for the different ANCOVA tables. For classification, the use of prescription glasses, issues with peripheral vision, and color blindness as covariates, participants were not evenly affected by these conditions to obtain accurate results. Not a single participant reported using medication that affects attention, so it was not possible to observe if this covariate could impact the results.

3.5.3. Discussion of Overall Findings

The visibility study compared two different types of displays that had different locations. A study analyzed symbol grid locations, and it was found that effectiveness varied by location (Perrin, Robillard, & Roy-Charland, 2017). This theory still holds true with displays. Eye-tracker technology has been used to evaluate the effectiveness of EXIT signs based on location and design (Zhang, Zheng, Hong, & Mou, 2015). Additionally, eye-tracker technology has been used in real life study were participants would drive while the eye-tracker collected data on the number of traffic signs that the user detected

(Topolšek, Areh, & Cvahte, 2016). These studies were used as a foundation for the creation of the visibility study, which addresses the gap in the literature for comparing attention-grabbing properties of displays in a dynamic environment.

While WTAT had higher luminous intensity and therefore more illuminance values than the TAT, the difference was minimal and is unlikely to have an effect on noticeability of displays. However, future studies should use displays with similar illuminous flux (lumens). The results from the visibility study showed that the WTAT had a significantly higher number of fixations than the TAT. As expected, the WTAT's wider and taller span that completely wraps around the door attracted significantly more attention. In addition, the doorknob had the second highest fixations. A potential explanation for this is that participants were primed to look down to read the checklists, so the doorknob had a higher probability of entering the participants' field of vision. The TAT's location and the fact that participants were primed to read could have been a factor that detracted attention from TAT. Future studies should investigate both head down and head up scenarios for a more comprehensive comparison of TAT and WTAT.

In addition, the WTAT had a significantly higher number of visits compared to the TAT. This may suggest that WTAT had more salient features. Another potential explanation is that while most participants might have seen LED displays similar to TAT, the LED strip used in WTAT might have been new to many. Therefore, participants might not have had a mental model of this new display resulting in a bottom-up process of perception which requires additional attention.

In addition, the gaze plots extracted from Tobii Pro Labs (Figure 14) were analyzed. The diameter of the circles indicates how long that particular fixation lasted, and how many fixations occurred overall. These gaze plots reveal that the TAT's display only had (3) fixations. In fact, as shown in Figure 14, in the WTAT condition, participants had more gazes (4) at the TAT display that was not active compared to TAT condition (3). This evidence suggests that the location of awareness displays above the door frame may be easily missed in head-down scenarios and when movement happens between two adjacent rooms. This is alarming since both of these scenarios frequently occur in ICUs especially when personnel review patient charts or document as they walk around the unit or when they move between adjacent rooms (e.g., for rounds).

The findings suggest that the LED strip utilized for WTAT has much higher chances of getting noticed by participants (both more fixations and for longer time) in head-down scenarios. In fact, further analysis showed that only one participant noticed the LED scrolling display and even in that one case the "Do not disturb" message was not effective as the participant still entered the room with no delays.

Also, as shown in Figure 14, the doorknob had more fixations concentrated in the smaller area compared to the WTAT that covered the most area. However, the WTAT received more fixations overall. This is because participants had to stop looking at the phone screen to find the doorknob and open the door. In addition, participants fixated more at the left side of the door (closer to the doorknob) when experiencing the LED strip condition. While most ICU doors are sliding, curtained, or open, future studies can investigate the design of handles, edges, and openings that serve as an indicator as a more

effective solution for heads-down scenarios. In addition, while searching for the doorknob, several signs on the door that provided information about the lab got noticed and received a large number of fixations. These were around eye-level of the participants, so when they had to stop looking at the screen to find the doorknob, these features proved to be noticeable.

Figure 14: Gaze plot WTAT's display (left side) and gaze plot TAT's display (right side), adapted from (Tobii AB, 2019)

The heat maps (Figure 15) show that the focus for visual attention for WTAT was distributed evenly around the display. However, there was a stronger concentration on the left side of the display which was in the direct line of sight when participants exited the

first room. The heath maps clearly show the lack of attention to the TAT display which suggests that the location of the display above the door frame may not be ideal for head-down tasks.

The heatmaps show that the most visually attended area of the door was the doorknob area in both conditions (TAT and WTAT) (Figure 15). This shows strong evidence that creating a doorknob that acts as an awareness display might be more effective at attracting attention.

Figure 15: Heat map WTAT's display (Left side) and heat map TAT's display (right side), adapted from (Tobii AB, 2019)

The findings from the interviews suggest that if participants assumed the role of nurses, 83.3% of participants would prefer the WTAT's display to communicate information. On the other hand, only 10% preferred the TAT's display, and 6.6% mentioned that a combination of both displays is preferred. Additionally, 76.6% of participants preferred the WTAT's display for door to door maneuvers or walking on a hallway while multi-tasking. Only 16.6% preferred the TAT's display, and 6.6% preferred a combination of both displays. This information was useful to assess that based on users' opinion the WTAT's display is better suited grabbing the attention of the users.

This study had limitations that need to be addressed. The gathered sample was small (30 participants) and led the results to have a large F- value. The sample was mainly composed of engineering students instead of nurses.

Additionally, the study was carried out in a university setting that does not resemble a hospital. The hallway where the study was carried out had carpeted floors which do not have refraction properties that hospital floors tend to have.

ICU doors tend to be wider than the door that was used for this study. Participants in this study were students rather than nurses. This study compared two static awareness displays. Dynamic awareness displays were not considered for this study. This study only considered one case scenario of nurses walking from a room to another at a 90° angle and did not consider walking on a hallway towards a door. This study required participants to read a checklist from a phone, so automatically participants were primed into having their field of vision tilted down, so this is a possible explanation as to why the TAT's display was significantly less noticed than the WTAT's display. It is also important to note that the

WTAT's display covered more area due to it being wrapped around the door frame, so even when participants were primed to look down, chances were higher for the WTAT's display to be within the field of vision of the participant. The study should be conducted in an actual ICU in order to properly evaluate how effective the displays are at grabbing attention.

There are several factors that should be taken into consideration when trying to decide which type of display will be used, such as, how complex is the message and if the user is familiarized with the system. If the message is complex then use the TAT's display, however, if the message is simple, then, use a binary message such as the WTAT's display. If users are trained in the use of the display, then it is possible to use the WTAT's display because if not users will not know what the intended message is and a violation of the system can occur. In this situation, a combination of both displays is highly recommended to have an extra layer of protection to make sure that the message is sent across.

This study can benefit the community by providing a foundation into how the effectiveness of displays can be assessed and reinforcing that the effectiveness of the display is impacted by the location of the display. For future studies, it would be beneficial to measure the participants' height and test if the received illuminance based on height had a significant effect on which display was gazed at the most by the participants. It would have also been beneficial to ask the participant for the dominant hand and assess if based on the dominant hand there was a preferred area to gaze at. In order to make the results more concrete, multiple conditions are needed to be tested to ensure that the displays are effective in a wide range of scenarios.

Another component that needs to be tested in a real scenario is the smartwatch actuator. Tests need to be done to connect multiple smartwatches to one RPI 3 and see if it can handle multiple interactions with the display. The smartwatch actuator needs to be validated by nurses, so it should be tested at an actual ICU. If multiple connections can be established successfully, then the idea of creating an interconnected ICU can be explored.

The overall goal will be to improve the working environment for nurses and reduce the number of errors due to interruptions that occur in the ICU. This is envisioned as to have a WTAT on each room within an ICU unit and nurses wearing the actuator smartwatch. The WTATS should connect to a server where the status of the room, user id, and nurse biofeedback can be unified and then projected to the nurse manager. The biofeedback can be analyzed, and the results can then be used by the nurse manager to assess if a nurse needs to take a break or rest. Knowing the status of the room can be beneficial to the nurse manager so that interruptions can be kept to a minimum.

4. CONCLUSIONS

The TAT was effective at mitigating negative interruptions. However, there were some limitations that needed to be addressed. The WTAT has addressed the proposed limitations of the TAT. It provides a solution to the fixed actuators and usability problem by having a smartwatch act as a wireless actuator that can be used for other purposes to reduce the mental workload of nurses. The WTAT's display proved to be significantly more effective at grabbing the attention of participants because it has a better location and covers more area.

The fixed location buttons were addressed by redesigning a new tool that allows for wireless control of the display with a smartwatch. This will improve nurses' experience due to the fact that the display can be activated from any location of the room. Additionally, the smartwatch offers more functionality for nurses because it can act as more than an actuator.

The visibility problem that was discussed with the TAT developer was addressed by a new display alternative, which showed promising results from the conducted study. This study can serve as a foundation for others who are interested in evaluating the attention-grabbing properties of displays using eye-tracker technology. The findings can be used to improve displays' effectiveness in the ICU.

This WTAT's design opened up the possibility to validate the WTAT in an ICU setting and incorporate it into a bigger system. There is always room for improvement in the ICU, and this tool can help nurses mitigate interruptions and reduce the mental

workload, thus making a better working environment. This will overall reduce the number of errors that occur due to interruptions in the ICU and provide better patient care. This next project is envisioned by having a WTAT per each ICU room and have the WTATS connect to a single server. The WTAT will upload the information into the server, and then this can be visualized using a display that is representative of the ICU. Informing the nurse manager of which room is in “Do not disturb” mode if nurses need help and scheduled activities for each nurse. This is what is envisioned as the Smart Nursing System, which will create an interconnected ICU.

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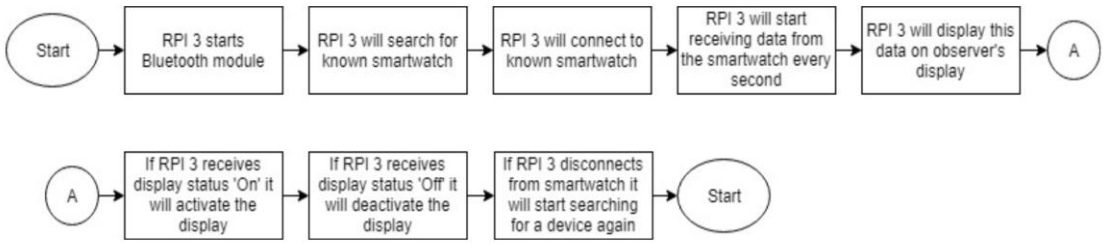
APPENDIX A

SOFTWARE DESIGN FOR PYTHON SCRIPT



APPENDIX B

RECRUITMENT EMAIL

Email Script for Investigating the Evaluation of Task-Awareness Display Alternatives

To: ISEN Department Student List Serve

Subject: Participants Needed for a Visibility study

Body:

The Applied Cognitive Ergonomics Laboratory of Industrial and Systems Engineering in Texas A&M University is seeking participants for a study that will evaluate the effectiveness of data being presented to the user while multi-tasking using a Tobii Pro 2 eyetracker. We are trying to understand how to better present data to the multi-tasking user.

The purpose of this study is to research how to better present information on a tablet to people when multi-tasking. The expected duration will be no more than 45 minutes, including rest time.

You will receive $10 upon the completion of study. If you need to withdraw from the study for any reason, prorated payment will be given based on the proportion of the study completed. You will be asked to sign for voice recordings obtained during the exit interview in the study.

Participants must:

- Have no physical disabilities, condition, pain, or injuries that interfere with walking, reduced field of vision, or have a color detection impairment
- Be able to speak, read, and write in English.
- Be at least 18 years old.

Pre-Registration is required.

For further inquiries about the study, or to schedule a time to participate, please contact Patricio Rodriguez at patricio.rodriguez@tamu.edu. Please pass this along to anyone you know who may be interested.

Thank you,

The Applied Cognitive Ergonomics Laboratory
Industrial and Systems Engineering, Texas A&M University

IRB NUMBER: IRB2018-0697D
IRB APPROVAL DATE: 09/03/2018

APPENDIX C

CONSENT FORM

CONSENT FORM

Investigating the Evaluation of Task-Awareness Display Alternatives

Introduction

The purpose of this form is to provide you with the information that may affect your decision as to whether or not to participate in this experiment. If you decide to participate in this study, this form will be used to record your consent.

The current research project involves using an eye tracker (Tobii Pro Glasses 2) to be able and understand how information might be better presented to a person when multitasking. In particular, we are interested in studying the emergent properties displays that convey information.

The way the eye tracker collects data is by tracking eye movements and calculate a trajectory to accurately predict what a person is looking at. First person video and audio will be collected. Additional collected data will consist of the frequency of saccade movements from the eye, and time it takes to be able to notice the screen. In addition to the questionnaire forms regarding demographic information a structured interview will be conducted at the end of the study to gather some feedback.

What will I be asked to do?

1. Please read through and sign this form if you have not done so.
2. Fill a form containing simple demographic questions.
3. Wear the eye tracker.
4. Calibrate the eye tracker.
5. Conduct two of the four experimental scenarios involving movement and reading
6. Take the exit interview.

In total, the entire duration of the above procedure is expected to be no more than 45 minutes.

What are the risks involved in this study?

Risks encountered in this study will be minimal. All risks are similar to those encountered in everyday life.

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What are the possible benefits of this study?

The proposed study will be a foundation for the display that will be used with the Wireless Task Severity Awareness Tool (WTAT).

Do I have to participate?

No. Your participation is voluntary. You may decide not to participate or to withdraw at any time without your current or future relations with Texas A&M University being affected.

Will I be compensated?

After the completion of the study you will receive $10 dollars. However, in any case that you must withdraw from the study before the completion of study, a prorated compensation will be given at the rate of $3 per 15 minutes.

Who will know about my participation in this research study?

Any interactions between you and the study team will remain confidential.

Whom do I contact with questions about the research?

If you have questions regarding this study, you may contact Patricio Rodriguez-Paras (patricio.rodriguez@tamu.edu) or Farzan Sasangohar (sasangohar@tamu.edu).

Who will have access to my study information?

The data we collected from you until this moment will be stored only if you signed this form. If you did not sign the form, the collected data will be destroyed immediately.

All data collected by this project will be archived in password protected computer in room 2023. Consent form and survey will be stored in a locked cabinet in 2024. A dataset may also be made publicly available. The public dataset will be deidentified and will not contain any information that might lead to the identification of an individual participant.

The collected data will also be stored in password-protected computers in Texas A&M University for the purpose of data analysis. Only the research personnel will have access to these computers.

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Information about you will be kept confidential to the extent permitted or required by law. People who have access to your information include the Principal Investigator and research study personnel. Representatives of regulatory agencies such as the Office of Human Research Protections (OHRP) and entities such as the Texas A&M University Human Research Protection Program may access your records to make sure the study is being run correctly and that information is collected properly.

Whom do I contact about my rights as a research participant?

This research study has been reviewed by the Human Subjects' Protection Program and/or the Institutional Review Board at Texas A&M University. For research-related problems or questions regarding your rights as a research participant, you can contact these offices at (979)458-4067 or irb@tamu.edu.

Will photos, video or audio recordings be made of me during the study?

The eye tracker records audio and video, but there is no way to identify the wearer of these from the video. The researchers will also take a recording of the interview so that your response can be recorded, only if you give your permission to do so. Indicate your decision below by initialing in the space provided. to give permission for the recording.

_____ I give my permission for photographs to be made of me during my participation in this study.

_____ I do not give my permission for photographs to be made of me during my participation in this study.

Signature for consent form

Please be sure you have read the above information, asked questions and received answers to your satisfaction.

By signing this document, you consent to participate in this study.

IRB NUMBER: IRB2018-0697D
IRB APPROVAL DATE: 10/02/2018

APPENDIX D

BACKGROUND QUESTIONNAIRE

Investigating Evaluation of Task-Awareness Display Alternatives
Background Questionnaire

Thank you for participating in our study! Please fill out this short background questionnaire.

1. Age: _____

2. Sex: M F

3. Classification: (Please circle one)

Undergraduate student

Graduate student: Master's Ph.D.

Professional (please describe):_____

4. Do you wear glasses: Yes No

5. Are you familiar with eye tracker devices: Yes No

6. Do you consume any medicines that affect your attention?: Yes No

7. Are you familiarized with a field of vision test? Yes No

8. Are you aware of issues with your peripheral vision? Yes No

9. Are you affected by color blindness? Yes No

IRB NUMBER: IRB2018-0697D
IRB APPROVAL DATE: 09/03/2018

APPENDIX E

CHECKLISTS THAT PARTICIPANTS WERE ASKED TO READ

Nurse 1 Checklist ACElabTAMU

Room: 2023 **Patient: Y**

- Stop by to check in with patient Y at room# 2023
- Take note of the vital signs of the patient
- Adjust the IV pumps to new suggested dose based on the doctor's recommendation
- Administer new medicine recommended by the doctor
- Inspect that equipment is properly placed on the patient
- Ask patient for any comments regarding how he is feeling, and if any discomfort is present

Room: 2023 **Patient: X**

- Stop by to check in with patient X at room# 2023
- Ask patient for any comments regarding how he is feeling, and if any discomfort is present
- Take note of the vital signs of the patient
- Administer new medicine recommended by the doctor
- Inspect that equipment is properly placed on the patient
- Adjust the IV pumps to new suggested dose based on the doctor's recommendation

Room: 2023 **Patient: Z**

- Stop by to check in with patient Z at room# 2023
- Adjust the IV pumps to new suggested dose based on the doctor's recommendation
- Ask patient for any comments regarding how he is feeling, and if any discomfort is present
- Take note of the vital signs of the patient
- Administer new medicine recommended by the doctor
- Inspect that equipment is properly placed on the patient

Nurse 2 Checklist ACElabTAMU

Room: 2023 Patient: Y

- Stop by to check in with patient Y at room# 2023
- Take note of the vital signs of the patient
- Adjust the IV pumps to new suggested dose based on the doctor's recommendation
- Administer new medicine recommended by the doctor
- Inspect that equipment is properly placed on the patient
- Ask patient for any comments regarding how he is feeling, and if any discomfort is present

Room: 2023 Patient: X

- Stop by to check in with patient X at room# 2023
- Ask patient for any comments regarding how he is feeling, and if any discomfort is present
- Take note of the vital signs of the patient
- Administer new medicine recommended by the doctor
- Inspect that equipment is properly placed on the patient
- Adjust the IV pumps to new suggested dose based on the doctor's recommendation

Room: 2023 Patient: Z

- Stop by to check in with patient Z at room# 2023
- Adjust the IV pumps to new suggested dose based on the doctor's recommendation
- Ask patient for any comments regarding how he is feeling, and if any discomfort is present
- Take note of the vital signs of the patient
- Administer new medicine recommended by the doctor
- Inspect that equipment is properly placed on the patient

APPENDIX F

PROCEDURE

Participant arrives at the lab.

Hello. How are you doing? My name is _____, and I'm a graduate student trying to complete my thesis.

You are participating in the Evaluation of the Task-Awareness Display Alternatives study. The research was approved by the Institutional Review Board at Texas A&M. Please spend a few minutes to review the consent form that explains the study goals and other important information. Feel free to ask me any questions you have. We don't collect any personal identifiable information from you to protect your privacy.

Once you finish reading please sign the consent form if you are willing to participate in the study.

[Once consent form is completed]

This are the Tobii Pro Glasses 2. This will help us understand the attention grabbing nature of the text that will be presented to you on a table while walking.

[Help participant wear the Tobii Pro Glasses 2]

[Complete the calibration process]

[Ask participant if there are any questions before proceeding]

[Take participant through scenario {3-5 minutes}]

[Return to the lab after scenario, and remove the eye tracker from the participant]

Thank you for completing the scenario. I wanted to ask you if you noticed a display (LED strip/Scrolling RGB) on the door before coming to the room? The true purpose of this study was to observe the emergent properties of the visual display and not from the text presented to you on the tablet. I am sorry for deceiving you, but in reality to be able to evaluate the displays it was absolutely necessary for you not to be expecting a display.

[Ask participants about their experience with the study, and if there are any questions]

I would like to ask you for your consent to participate in a small interview that will help me gather more data in regards to your opinion on the display. This interview will take no more than 5 minutes. Are you willing to participate?

[End interview, thank the participant, and hand over compensation]

IRB NUMBER: IRB2018-0697D
IRB APPROVAL DATE: 09/03/2018

APPENDIX G

EXIT INTERVIEW

Semi-Structured Exit Interview

Investigating Evaluation of Task-Awareness Display Alternatives

Interview Script

Thank you for participating in this study. I am going to ask you a few questions about your experience in the study. Is it fine is we record the session? (If yes, turn on audio recording).

1. Where you able to notice a display above the door from the lab?

2. Do you think that the display was effective at grabbing your attention while reading and walking towards the display?

3. What do you think of this other display (show alternative display to participant)?

4. Do you think it will be effective?

5. Which one would you prefer assuming you had to go from door to door or walking on a hallway while multitasking?

6. Overall, if you had to choose only one display to serve the purpose, which one will you prefer assuming you are a nurse at a hospital for example?

IRB NUMBER: IRB2018-0697D
IRB APPROVAL DATE: 09/03/2018

APPENDIX H

ANCOVA ANALYSIS TO FIND COVARIATE EFFECT IN AOI FC

Table 10: ANCOVA results for fixation count with age as a covariate

ANCOVA - AOI FC

Cases	Sum of Squares	df	Mean Square	F	p
WTAT = 1, TAT = 2	57.161	1	57.161	9.337	0.003
Age	8.798	1	8.798	1.437	0.236
Residual	330.570	54	6.122		

Note. Type III Sum of Squares

Table 11: ANCOVA results for fixation count with gender as a covariate

ANCOVA - AOI FC

Cases	Sum of Squares	df	Mean Square	F	p
WTAT = 1, TAT = 2	57.78	1	57.781	9.574	0.003
Gender M=1,F=0	13.49	1	13.486	2.235	0.141
Residual	325.88	54	6.035		

Note. Type III Sum of Squares

Table 12: ANCOVA results for fixation count with classification as a covariate

ANCOVA - AOI FC

Cases	Sum of Squares	df	Mean Square	F	p
WTAT = 1, TAT = 2	58.27	1	58.269	9.734	0.003
Classification (U=1, G=2, P=3)	16.13	1	16.131	2.695	0.106
Residual	323.24	54	5.986		

Note. Type III Sum of Squares

Table 13: ANCOVA results for fixation count with wearing glasses as a covariate

ANCOVA - AOI FC

Cases	Sum of Squares	df	Mean Square	F	p
WTAT = 1, TAT = 2	57.200	1	57.200	9.220	0.004
Wear glasses (Y=1, N=0)	4.371	1	4.371	0.705	0.405
Residual	334.997	54	6.204		

Note. Type III Sum of Squares

APPENDIX I

ANCOVA ANALYSIS TO FIND COVARIATE EFFECT IN AOI VC

Table 14: ANCOVA results for visit count with age as a covariate

ANCOVA - AOI VC

Cases	Sum of Squares	df	Mean Square	F	p
WTAT = 1, TAT = 2	27.236	1	27.236	12.907	< .001
Age	4.054	1	4.054	1.921	0.171
Residual	113.945	54	2.110		

Note. Type III Sum of Squares

Table 15: ANCOVA results for visit count with gender as a covariate

ANCOVA - AOI VC

Cases	Sum of Squares	df	Mean Square	F	p
WTAT = 1, TAT = 2	27.519	1	27.519	13.272	< .001
Gender M=1,F=0	6.033	1	6.033	2.910	0.094
Residual	111.966	54	2.073		

Note. Type III Sum of Squares

Table 16: ANCOVA results for visit count with classification as a covariate

ANCOVA - AOI VC

Cases	Sum of Squares	df	Mean Square	F	p
WTAT = 1, TAT = 2	27.686	1	27.686	13.358	< .001
Classification (U=1, G=2, P=3)	6.076	1	6.076	2.931	0.093
Residual	111.923	54	2.073		

Note. Type III Sum of Squares

Table 17: ANCOVA results for visit count with wearing glasses as a covariate

ANCOVA - AOI VC

Cases	Sum of Squares	df	Mean Square	F	p
WTAT = 1, TAT = 2	27.130	1	27.130	12.448	< .001
Wear glasses (Y=1, N=0)	0.313	1	0.313	0.144	0.706
Residual	117.686	54	2.179		

Note. Type III Sum of Squares