THE EFFECT OF SCREEN SIZE ON MISSION COMMANDER'S SITUATION AWARENESS

Hsiao-Ting Hsu*, Michael Mason*, Duncan A. Campbell*
***Australia Research Centre of Aerospace Automation, Brisbane, QLD, Australia.**
h5.hsu@student.qut.edu.au; m.mason@qut.edu.au; da.campbell@qut.edu.au

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Abstract

Situation awareness lost is a common factor leading to human error in the aviation industry. However, few studies have investigated the effect on situation awareness where the control interface is a touch-screen device that supports simultaneous multi-touch input and information output. This research aims to conduct an experiment to evaluate the difference in situation awareness on a large screen device, DiamondTouch (DT107), and a small screen device, iPad, both with multi-touch interactive functions. The Interface Operation and Situation Awareness Testing Simulator (IOSATS), is a simulator to test the three basis interface operations (Search Target, Information Reading, and Change Detection) by implementing a simplified search and rescue scenario. The result of this experiment will provide reliable data for future research for improving operator's situation awareness in the avionic domain.

1 Introduction

Ensley [1] defined situation awareness (SA) as "The perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." Three levels of SA are determined according to this definition. Level 1 SA is the perception of elements in the environment within a volume of time and space. Level 2 SA is the comprehension of the elements' meaning. Level 3 SA is to project the near future depending on the understanding on Level 2 SA.

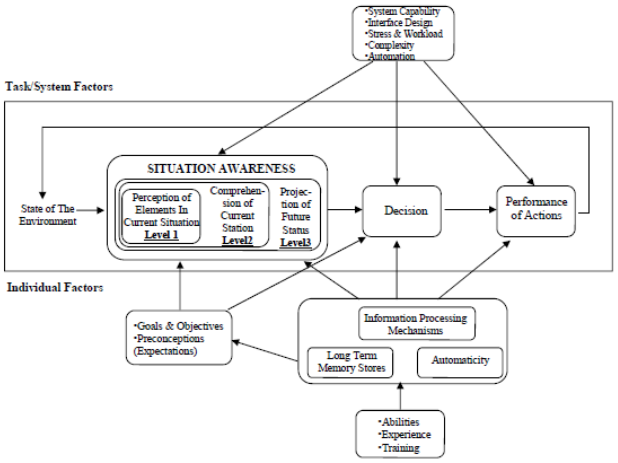

Fig. 1 Aircrew decision making procedure [2].

Fig. 1 presents an aircrew decision making procedure to illustrate the concept of SA. Initially, environmental information is completely received by the operator's sensing organs and there is no information lost during this stage. The information then enters the Situation Awareness stage. If all information is observed by the operator, then Level 1 SA is successful and the information enters Level 2 SA. During Level 2 SA, the operator analyses all the information to understand the meaning of the information and also to distinguish between useful and useless information. When the procedure moves to Level 3 SA, the operator combines all the useful information to project the near feature situation. The operator only can reach higher level of SA when the lower levels of SA are satisfied. During the Decision stage, the operator will make a decision

according to the near future situation projected in Level 3 SA. Then the operator performs the actions according to the decision in Performance of Actions stage. The procedure is also affected by many factors other than immediate environment stimulus. For example, the operator may analyse and project the near future situation according to their previous experience, the operator may decide not to use the most suitable method to solve the problem due to limiting self capabilities, the operator may receive or analyse wrong information due to the hardware issues, to name a few.

A Level 1 SA Error occurs when the operator fails to perceive the presented information. Incorrect analysis of information constitutes a Level 2 SA Error. Finally, using the correct information but making an incorrect projection is a Level 3 SA Error [3]. An interface design that considers the impact on user SA can enhance operation performance, efficiency and safety. SA has been pointed out as an important factor affecting avionic interface design. For example, Federal Aviation Administration (FAA) in USA has developed a document to guide the interface design for current air traffic control system [4].

SA can be measured using various methods. One of the common methods aims to measure using physical equipment by detecting physiological responses of the operator such as eye movement, skin temperature, heartbeat frequency, to name a few. However, these methods require particular equipment and cannot measure higher level SA [5].

Situation Awareness Global Analysis Technique (SAGAT) was developed by Endsley to evaluate SA in dynamic systems [2]. SAGAT can be applied to any system to test the operator's SA by asking questions. SAGAT provides the operators a sample trial before a formal trial to avoid the operator running the formal trial with unfamiliar operation. Both trials will stop the operation at random times and ask the operator a number of questions in order to test their SA. Once the operator finishes the questions, the trials will continue and stop at another random time to ask another set of questions. The procedure is repeated until all the questions are asked to complete the trials. Questions at random intervals are necessary as SAGAT is designed to measure the operator's SA in normal operating conditions; the operator will improve concentration if they expect a question is imminent. The questions asked using the SAGAT method are designed using a cognitive task analysis named Goal-Directed Task Analysis (GDTA) [6].

According to Fig. 1 model, there are many factors that affect task performance and research from various domains has shown that human-machine interface (HMI) screen size is a significant issue [7–9]. Most existing literature examines the difference in performance between monitors of two difference sizes. However, few researches have investigated whether the change of performance is due to loss of SA or other factors. Furthermore, studies investigating screen sizes focused on tradition fixed, display only monitors as opposed to newer touch-screen devices that support simultaneous multi-touch input and information output [7, 8].

This research aims to analyse how screen size affects SA and the resulting effect on performance. This research targets three particular interface actions: Search Target (ST) [10], Information Reading (IR) [9], and Change Detection (CD) [11]. ST is to search a particular target in a given area. IR is to read the information on the particular target. CD is to discover the any different changes during the operation. The test devices to be used in this experiment are the iPad and the DiamondTouch DT107 [12] (respectively 9.7 and 47 inches diagonally). 30 volunteers will be recruited to conduct the experiment.

2 Experiment Design

The interface program, Interface Operation and Situation Awareness Testing Simulator (IOSATS), is a simulator designed in this research to test the three basis interface operations (ST, IR, CD). IOSATS implements a simplified search and rescue (SAR) scenario [13] and is designed to operate on both the large and small screen devices. Test subjects will carry out tasks using IOSATS, answering questions asked

by the program and their responses recorded by IOSATS. Finally, responses will be extracted and analysed to determine any difference in SA between the two devices.

2.1 Simulation Scenario

The scenario implemented in the experiment is a SAR mission. The operator is assigned as a mission commander to manage all search units and rescue units within a SAR area. The search units are used to locate missing people (target), and rescue units are used to retrieve them. Both search and rescue units include air units and ground units. There are three air search units, five ground search units, one air rescue unit and two ground rescue units. The responsibilities of the operator are to manage these units to search and rescue eight missing targets. The location of each missing target is randomly assigned by IOSATS.

2.2 Interface

An example of IOSATS interface is presented in Fig. 2 with key features labelled alphabetically. IOSATS manages the experiment difficulty by creating environmental restrictions limiting air and ground units. These features and restrictions are outlined as follows:

A. The Base:

The star icon is the base of SAR mission and all search and rescue units are deployed from the base. The units also return to this base to refuel and drop off a rescued target.

B. Environment Restrictions:

The restrictions the operators have to consider includes: (1) a rain storm (size 250×250 pixels) is dynamically moving around the SAR area. Air units stop when they are near the rain storm; (2) a long river crosses to the SAR area. Ground units cannot move over the river.

C. Path Draw:

The operator directs the moving pattern of search and rescue units by drawing a line on the touch input surface. The operator can change the units' moving pattern at any time.

D. Operation Bar:

The Operation Bar can appear and disappear by tapping the screen with three fingers. The three functions of the Operation Bar include: (1) calling out air and ground search units; (2) calling out air and ground rescue units; (3) calling out the Information Bar. The numbers under the "Air" and the "Ground" buttons represent the number of air or ground units left in the base.

E. Information Bar:

The Information Bar includes two sections: (1) Target Information and (2) Search and Rescue Units Information. Target Information contains details of the eight missing targets including their name, health status and rescue status. Search and Rescue Units Information contains the number of search and rescue units left in the base. The Information Bar automatically appears and disappears every 10 seconds to provide information while avoiding blocking parts of the map for too long.

F. Clock:

A clock is placed on the interface indicating the remaining time for the experiment. The colour of the clock turns to red when the clock count downs to three minutes and IOSATS stops when the time is up. The original position of the clock is on the bottom left hand corner of the interface and can be moved by the operator if desired.

Other Functional Limitations:

Other functional limitations include: (1) Once the rescue unit has retrieved a missing target, it must return the target back to the base before it can rescue another target. (2) A search or rescue unit will automatically return to the base without the operator's command once the unit does not have enough fuel to finish the task.

Missing Target:

A missing target is represented by 30×30 pixels icon on the map. A health status bar under the icon represents the health level of the target. Each target has a random health level assigned when the simulation starts and the health bar decreases at a rate of 3% per second once the person is found. The icon background colour turns to yellow when the target health is worsening (less than 33%) and red indicates the target has deceased (0%).

The interface icon dimensions and movement

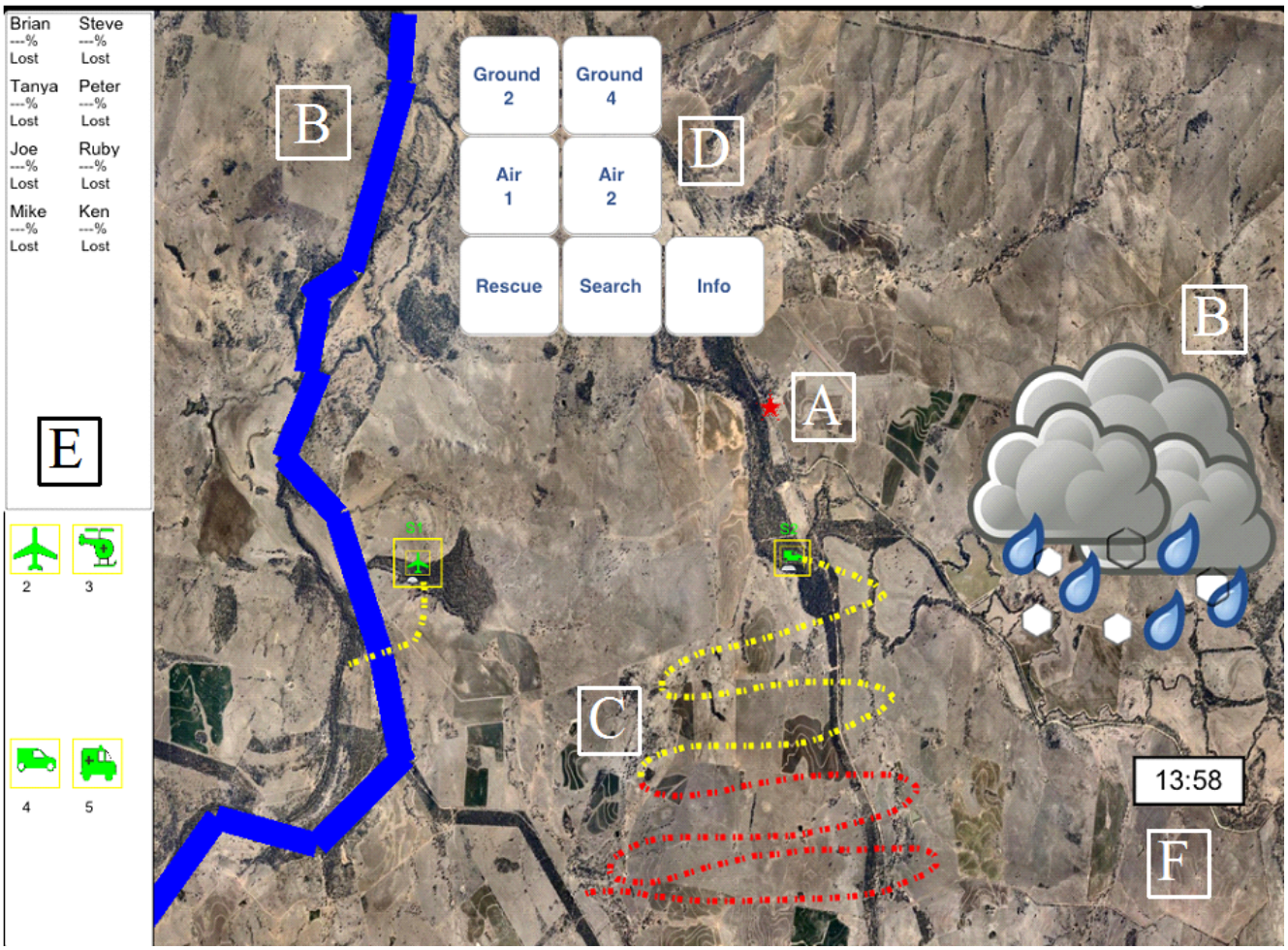

Fig. 2 IOSATS Interface. A. The Base; B. Environment Limitations; C. Path Draw; D. Operation Bar; E. Information Bar; F. Clock

speed of search and rescue units are indicated in Table 1. Each unit has a bar indicating the unit's level of fuel under its corresponding icon. The search and rescue units' background colour turn to red when the units have low fuel level (less than 25%). The rescue unit's background colour turns to blue when the rescue unit has retrieved a target. A time bar appears on the top of a rescue unit indicating the time required to complete a rescue action when the rescue unit arrives at a destination.

2.3 SAGAT Interface

Four types of SAGAT questionnaire interface are designed. Type One questions are multiple choice questions. Type Two questions require selecting one or more units on the map. Type Three questions require identifying the location of a particular subject. Type Four question requires entering a numeric answer. The questions randomly appear according to the current situation. Eighteen (18) SAGAT questions will be asked during the formal trial.

The SAGAT questions in IOSATS are categorised by the three interface actions (TS, IR, CD) to test three SA levels. Example of SAGAT questions are presented in Table 2.

2.4 Equipment

Two multi-touch enabled devices are used in the experiment. The smaller device, first generation iPad, is manufactured by Apple Inc. and has diagonal screen size of 9.7 inches. The larger device, DT107, is manufactured by Circle Twelve

Table 1 Search and Rescue unit specifications.

	Icon size (pixels)	SAR operation size (pixels)	Movement speed (pixels/second)
Air Search Unit	40×40	40×40	100
Ground Search Unit	30×30	30×30	30
Air Rescue Unit	20×20	35×35	100
Ground Rescue Unit	20×20	35×35	30

Table 2 Sample SAGAT questions

Action	SA Level	Sample Question
ST	1	Indicate the current location of the rain storm.
	3	Indicate Bill's current location.
IR	1	How many ground rescue unit(s) is/are left in the base?
	2	What was the most recent notification about?
CD	2	How many rescue unit(s) has/have low fuel?
	3	Tap the unit(s) that is/are currently available to perform a task.

Inc. and has diagonal screen size of 47 inches. Both devices have aspect ratio of 4:3. The resolution is set to 1024×748 pixels for both devices.

2.5 Experiment Procedure

The same graphical user interface is used on both the iPad and the DT107. Thirty (30) volunteers from undergraduate or post-graduate students in Queensland University of Technology (QUT) are required for this experiment. The experiment room is set up in the Australian Research Centre for Aerospace Automation (ARCAA).

After an introduction of the experiment, the volunteers are required to stay in a quiet room to reduce other factors that may affect their SA. To avoid bias, half of the volunteers will conduct the experiment on the iPad first and then on the DT107, while the other half will conduct the experiment in reverse order. A pre-experiment survey is required to be completed by the volunteers to understand their technical background.

The volunteers will first conduct the sample trial when the experiment starts. The sample trial is designed to allow the volunteers to familiarise with the basic operations of IOSATS and the SAGAT questionnaire format. This trial is untimed and answers to questions are not recorded or used in the final analysis. The formal trial is 20 minutes long and IOSATS will force stop the simulator when the experiment time is completed. Any remaining or missing targets will be considered as deceased by the simulator.

A QUT ethic clearance has been approved to have a low risk experiment with human involved. The risk of this experiment is not greater than everyday computer use.

2.6 Data Analysis and Hypotheses

SAGAT answers are collected by IOSATS during the experiment to be analysed to determine if there are any statistical differences of operator SA between large and small screen devices. If there are significant SA differences, the data will be analysed to determine which interface actions and SA level achieve better results on the two screen sizes. The results of this experiment can be used to determine whether the larger or the smaller screen devices are suitable for specific interface actions and where to focus to improve SA on these devices.

3 Conclusion

In conclusion, this paper presented the experiment proposal to investigate how screen size of touch enabled devices affect SA. Thirty (30) volunteers will be recruited to test the SA difference on two screen size devices, DT107 and iPad. IOSATS is designed to evaluate the operator's SA by using the SAGAT method. The results of this experiment will benefit systems that require large screen size devices to collaborate with small screen size devices. Further development of this research aims to improve operator SA on these devices.

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