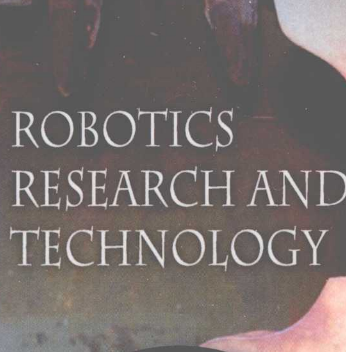
Scaling Robotic Controls and Displays for Army Soldiers

ROBOTICS RESEARCH AND TECHNOLOGY



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PREFACE

Scalability has been given many different definitions, depending upon the background of the person defining it, the technology being considered, and the operational use of the technology. Typically, when interface designers talk about scalable interfaces they are referring to a design that ensures that development takes into account the requirement to change over time. Without this type of scalability, interface designs require a complete renovation when a small change is needed in the application. This book examines the process of scaling robotic controls and displays for army soldiers.

Chapter 1- Scalability has been given many different definitions, depending upon the background of the person defining it, the technology being considered, and the operational use of the technology. Typically, when interface designers talk about scalable interfaces they are referring to a design that ensures that development takes into account the requirement to change over time. This drives interfaces to be flexible and "future proof". Without this type of scalability, interface designs require a complete renovation when a small change is needed in the application. This is a broad definition of scalability and has application to robotic interfaces. For this experiment, we concentrated on a more narrow definition of scalability which is a component of the broader definition. We are concerned with the ability of interfaces to accommodate presentation on devices of different types and sizes as effectively as possible. Soldiers operate in a large range of environments, from the relatively stable and spacious environment of a tactical operations center (TOC) to the cramped and perpetual motion environment of a vehicle to the rugged and physically demanding environment of the dismounted Soldier. All these environments have an impact on the size and configuration of the robotic interface. It is easy to see that a dismounted Soldier cannot carry the relatively large controller that can be used in a TOC. This type of scalability of interfaces is very important because it ensures that training transfer is easy across environments and that interfaces can be tailored to the environment in which they are used.

Chapter 2- Several streams of research are under way to delineate the degree and manner in which robotic controllers and displays can be scaled to the needs of Army Soldiers (Barnes, Knapp, Tillman, Walters, & Velicki, 2000; Barnes, Everett, & Rudakevych, 2005; Chen, Haas, & Barnes, 2007; Chen, Haas, Pillalamarri, & Jacobson, 2006; Renfro, Merlo, Duley, Gilson, & Hancock, 2007; Stafford, Jingjing, Merlo, & Hancock, 2007; Stafford, Hancock, Graham, & Merlo, 2007). This experiment is the second in a series of experiments designed to investigate current and future options for scaling robotic controls and displays specifically for use by dismounted Soldiers. The term "scalability" encompasses the various ways in which devices can be made more operationally effective, not only in terms of size and weight but also in terms of more intuitive display of information, enhancement of training transfer among other Army controls and displays, and minimization of information overload. For example, one operational definition of scalability is "The transmission of critical information to the Soldier tailored for each level of combat to ensure mission success while maximizing survivability by minimizing equipment requirements; minimizing multitasking workload, maximizing situation understanding; and maximizing aerial and ground robotic mission effectiveness" (Merlo, 2006). A similar definition is "The tailored reception and transmission of mission-essential information at the appropriate level for the Soldier, to ensure mission success while maximizing the survivability and lethality through the synergistic interaction of equipment requirements, appropriate cognitive workload, situation awareness and understanding for oneself and others connectivity of distributed intelligent agents" (Barnes, 2006).

Chapter 3- Speech-based systems are being investigated for many different applications. Speech-based systems have been evaluated for data entry (Mitchard and Winkles 2002; Tsimhoni et al., 2004), use by the disabled (Summers, 1988), assistance during medical examinations (Bravo, 2005), searching the web on handheld devices (Chang et al., 2002), and unmanned aerial vehicle (UAV) control (Draper et al., 2003). Speech-based input is an intuitive form of system control that can free both cognitive and physical operator resources. While speech-based systems show potential for military applications to free the hands and eyes during data input, they are not without potential problems. A primary challenge is intelligibility as affected by factors such as stress, noise, and speech mannerisms. These conditions are stated very well by Pigeon et al. (2005):

Chapter 4- This is the third in a series of experiments designed to investigate how best to scale robot controls and displays for dismounted Soldiers who need smaller and lighter devices. The first two experiments in this series addressed screen size for the dismounted Soldier's driving camera display (Redden, Pettitt, Carstens, and Elliott, 2008) and controller options for the dismounted Soldier to drive the robot and maneuver the robotic arm (Pettitt, Redden, Carstens, and Elliott, 2008). The environments of dismounted Soldiers are rugged and physically demanding, and Soldiers must carry their robotic operator control units (OCU) along with all their protective and fighting equipment in these challenging environments. Relatively large displays typically used in a stationary environment or inside a combat vehicle are not appropriate and could have an adverse impact on the dismounted Soldiers' missions. Scaling robotic interfaces involves the design and development of smaller, lighter versions that are still rugged, easy to use, easy to learn, and easy to maintain. Scaling ensures that training transfer is easy across environments and that interfaces are tailored to the environment in which they are used. The key to successful scaling is to consider the range of devices that Soldiers will use (e.g., vehicle-mounted robot control devices, other controller devices) and also their context of use. A smaller controller may be easy to learn and use if it is similar to existing controllers. On the other hand, some controller characteristics will not be as effective in a smaller unit. Consider the increased difficulty of typing on a QWERTY keyboard on a cell phone compared to a computer keyboard. Context of use also becomes a factor, when Soldiers must use their displays in rough terrain, in bright daylight, or perhaps, while on the move. Trade-offs in controller options for different task demands must be recognized and considered. Ultimately, scaling depends on user evaluations and experimental controlled investigations under realistic task demands.

CONTENTS

In: Scaling Robotic Controls and Displays for Army Soldiers ISBN: 978-1-61324-290-2
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Chapter 1

SCALABILITY OF ROBOTIC DISPLAYS: DISPLAY SIZE INVESTIGATION*

Elizabeth S. Redden, Rodger A. Pettitt, Christian B. Carstens and Linda R. Elliott

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of the use thereof.

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[1] DCS is not an acronym.

Adams Greenwood-Ericksen from the University of Central Florida (UCF), and Freddy Heller and SFC Jim Taylor from ARL for their assistance with data collection. The help from LTC James Merlo from UCF and Mr. Jeff Williams from the Soldier Battle Lab in developing the scenario and laying out the course was instrumental in ensuring that the experiment tasks were militarily relevant and produced valid data, and we would like to thank them as well.

1. INTRODUCTION

1.1. Statement of the Problem

Scalability has been given many different definitions, depending upon the background of the person defining it, the technology being considered, and the operational use of the technology. Typically, when interface designers talk about scalable interfaces they are referring to a design that ensures that development takes into account the requirement to change over time. This drives interfaces to be flexible and "future proof". Without this type of scalability, interface designs require a complete renovation when a small change is needed in the application. This is a broad definition of scalability and has application to robotic interfaces. For this experiment, we concentrated on a more narrow definition of scalability which is a component of the broader definition. We are concerned with the ability of interfaces to accommodate presentation on devices of different types and sizes as effectively as possible. Soldiers operate in a large range of environments, from the relatively stable and spacious environment of a tactical operations center (TOC) to the cramped and perpetual motion environment of a vehicle to the rugged and physically demanding environment of the dismounted Soldier. All these environments have an impact on the size and configuration of the robotic interface. It is easy to see that a dismounted Soldier cannot carry the relatively large controller that can be used in a TOC. This type of scalability of interfaces is very important because it ensures that training transfer is easy across environments and that interfaces can be tailored to the environment in which they are used.

Interface trends are moving away from "one size fits all" toward a scalable family of products with common architecture, but sizes depend on the role and mission. The key to ensuring that a system is scalable is to consider not only the range of devices that Soldiers will use but also their context of use. An example can be easily seen in e-mail access. Typically, individuals have used their desktop computers to access e-mail, but more frequently, they are now using personal digital assistants (PDAs) and cell phones to do the same job when they are outside their offices. One factor affecting scalability of displays to the environment is screen size. Designing for one "optimum" screen size may seem to be a good idea because it may seem that the presentation of the interface is being controlled. If a display is designed that only works on one "fixed" browser window size, it will not work well in the others. It might even be completely unusable if important features disappear off the edge of the screen.

Many current robots (i.e., the MATILDA[2], PackBot[3], and TALON[4]) provide a tele-operation interface that is large and heavy. A goal of Program Executive Office (PEO) Soldier Warrior is to design and build an innovative universal robot controller that allows a dismounted Soldier to control and task various small robotic platforms without causing unnecessary additional weight and without bulky "add-ons" to the Infantry Soldier System. Since current robotic interfaces would add much weight to the dismounted Soldier, it is important to discover and document the range of interface sizes that can be used for robotic operations in different environments and to understand the trade-offs involved in tailoring the sizes to the environments in which they will be used.

The popularity of very large screen displays and small, portable, wearable computing devices is increasing. The motivation behind the development for many of the large screen displays is often to provide an immersive experience or a sense of presence for virtual reality and home theaters. There are several configurations for these displays (i.e., projection screen, liquid crystal display [LCD], plasma, etc.), and the prices for these systems are dropping. The use of large displays for robotic interfaces might allow a more immersive experience for the operator than is allowed by a smaller desktop size display (Tan, Gergle, Scupelli, & Pausch, 2003). Tan, Robertson, and Czerwinski (2001) found that the wide fields of view afforded by large displays also provided better cues to aid users in navigating virtual space. Although this avenue of investigation is an interesting one, the number of feasible display sizes (large and small) is too large to address in one experiment. This experiment focuses on the PEO Soldier goal of reducing the size of the interface for use by dismounted Soldiers in real-world environments and on the task of driving a well-marked course while situational awareness (SA) is maintained by the search for targets in the immediate area. In order to bound even the number of sizes of smaller displays, we focused on display sizes that are currently available (or will be available in the near future) to the dismounted Soldier. The thought here is that a Soldier might not have to carry a separate display for robotic control, but rather, s/he could control a robot using a display that s/he is already carrying. The four display sizes we investigated were the Force XXI Battle Command Brigade and Below (FBCB2) that is currently available in vehicles, the commander's digital assistant (CDA) that is being carried by lower echelon commanders, a PDA that is being considered for squad members by the Future Force Warrior (FFW) program, and a goggle-mounted display (GMD) that is being considered for squad leaders by the FFW program.

1.1.1. The FBCB2 Display

The FBCB2 forms the principal digital command and control (C2) system for the Army at brigade levels and below. It is a 7.3-pound, 2.36-inch by 13.1-inch by 9-inch high-resolution active matrix touch screen display (see figure 1). The screen is a super video graphics array 12.1 inches diagonal with 800x600-pixel resolution.

1.1.2. CDA Display

The CDA is an early "spiral-out" from Land Warrior that provides a tactical picture to company-level leaders and above. There is more than one model that uses the name CDA. The CDA, developed from Raytheon's air warrior digital kneeboard, measures approximately 7 by 10 by 2 inches and weighs 5.4 lb, including its battery. It has a 6.4-inch diagonal daylight readable 480x640 resolution color LCD with an integrated touch screen (see figure 2).

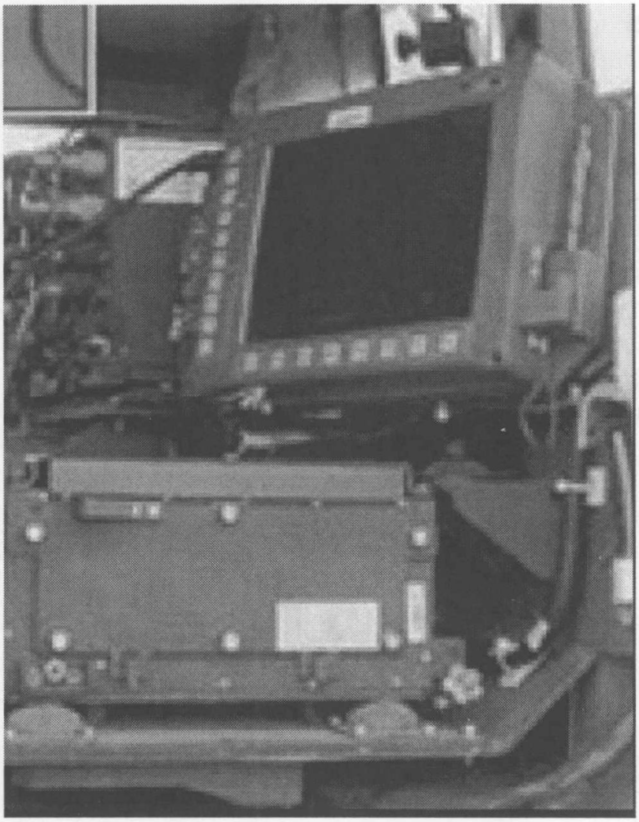

Figure 1. FBCB2 display.

Figure 2. CDA display.

1.1.3. PDAs

PDAs are potentially attractive interfaces for dismounted Soldiers because they are relatively inexpensive, lightweight, small, and extremely portable, and some feature touch-sensitive displays. Many standard PDA interfaces have been developed for a wide range of applications such as word processing, calendar management, calculators, educational tools, and mobile surveillance. The FFW digital assistants also display navigation and SA pictures and images received from team members. The Recon 400 X used by the FFW Soldiers during the Air Assault Expeditionary Force (AAEF) Spiral C had a display resolution of 240x320 pixels, a 3.5-inch diagonal display size, and weighed 17 ounces (see figure 3).

Figure 3. Vehicle target detection rates by distance, open field target detection, no smoke.

1.1.4. Head-Mounted Displays (HMDs) and GMDs

Small, wearable HMDS and GMDs are being developed that enable users to observe a high-resolution display without having to carry a bulky display or without restricting the user to small size and low resolution. These devices come in a variety of configurations (monocular, binocular, see-through, opaque, etc.). Some are mounted on straps worn around the head, some are mounted on helmets, and some are mounted on eyewear. The FFW program is investigating several of these displays for use by the squad and team leaders. Typically, these devices provide lightweight (~17 ounces) super-video graphics display, high resolution (800x600) pictures with a 1.425-inch diagonal picture. The device used in this study was a monocular GMD. Because this display was so close to the eye, its apparent size was like that of a 17-inch diagonal TV display (see figure 4).

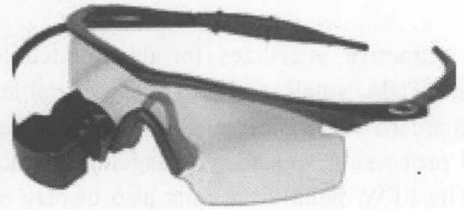

Figure 4. GMD.

1.2. Objectives

The objective of this experiment was to determine what effect display size reduction has on the tele-operation (driving) of small robots and the operator's SA of the immediate vicinity of the robot.

2. METHOD

2.1. Participants

Thirty-two Soldiers from the Officer Candidate School (OCS), Fort Benning, Georgia, participated in the study. These Soldiers had experience as enlisted Soldiers and came from varied military occupational specialties (MOSs).

2.2. Instruments and Apparatus 2.2.1 TALON Robot

The TALON is a lightweight robot designed for missions ranging from reconnaissance to weapons delivery (see figure 5). Built with all-weather, day/night and amphibious capabilities, the TALON can operate during adverse conditions over almost any terrain. The suitcase-portable robot is controlled through a two-way radio frequency line from a portable operator control unit that provides continuous data and video feedback for precise vehicle positioning. It was developed for the Explosive Ordnance Disposal Technology Directorate of the U.S. Army's Armament Research, Development, and Engineering Center at Picatinny Arsenal, New Jersey, by the engineering and technology development firm of Foster-Miller. The TALON began being used in military operations in Bosnia in 2000, deployed to Afghanistan in early 2002, and has been in Iraq since the war started, assisting with improvised explosive device (IED) detection and removal.

For this experiment, the TALON was equipped with a video camera that enabled the participants to maneuver the vehicle and assess enemy activity and IEDs along the road to the objective.

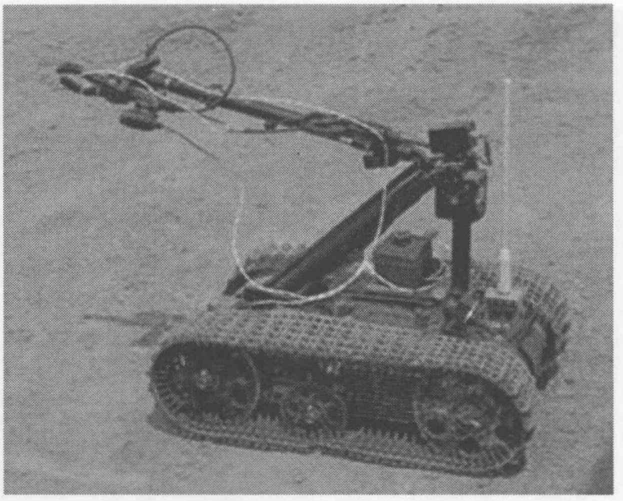

Figure 5. TALON robot.

2.2.2. Robotic Vehicle Displays

Four different display sizes were used to conduct this experiment. The A, B, and C display configurations were presented on an iExplorer to control the number of variables present in the study. Both the iExplorer (see figure 6) and the GMD (see figure 7) were plugged into the existing TALON control system so that its radio could be used. However, the TALON control system joystick and display were not used.

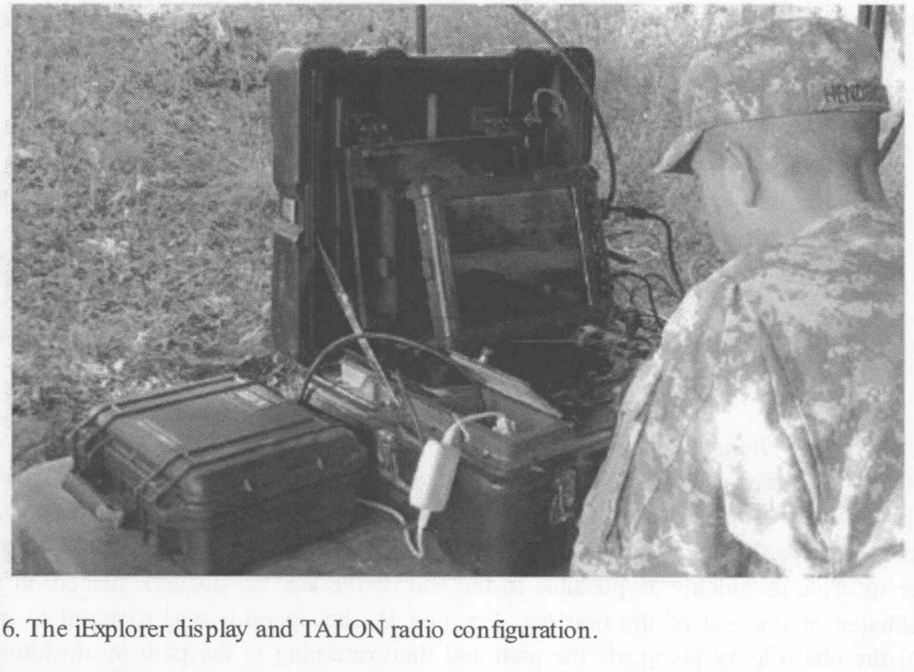

Figure 6. The iExplorer display and TALON radio configuration.

Figure 7. The GMD and TALON radio configuration.

The four display configurations (sizes or types) were representative of displays that can be used in the field or that may soon be present. The display configurations used were

- Display A – A display based on the Stryker and Bradley FBCB2 display characteristics (a 10.4-inch diagonal screen with 800x600 pixels);
- Display B – A display based upon the CDA display characteristics (a 6.5-inch diagonal screen with 640x480 pixels);
- Display C – A display based upon the FFW PDA display characteristics (a 3.5-inch diagonal screen with 240x320 pixels); and
- Display D – A GMD display based on the FFW GMD display characteristics (a 1.425-inch diagonal screen with 800x600 pixels).

2.2.3. Robotic Driving Course

The robotic driving course consisted of an oval-shaped course with four different lanes. Each lane had three legs and a total length of approximately 300 meters (see figure 8). Leg A, the first leg of each lane (see figure 9), was marked with engineering tape and required the Soldier to drive as quickly as possible to the end of the leg. An obstacle placed on the path was situated at the end of the first leg. For Leg B, the operator was required to negotiate around the obstacle by going off the path and then returning to the path by the shortest and easiest route (see figure 10). Mock-up enemy Soldiers, booby traps, IEDs, and mines (see figure 11) that could be clearly seen by the driving camera were placed along the rest of the lane (Leg C) between the obstacle and the objective (end of the course). The robotic operators tele-operated the TALON from inside a tent that was placed behind a berm that blocked the line of sight (LOS) between the operators and the course. The tent and its placement prevented the operator from tele-operating the vehicle by using LOS rather than the display. It also kept the operator and the equipment out of the elements.

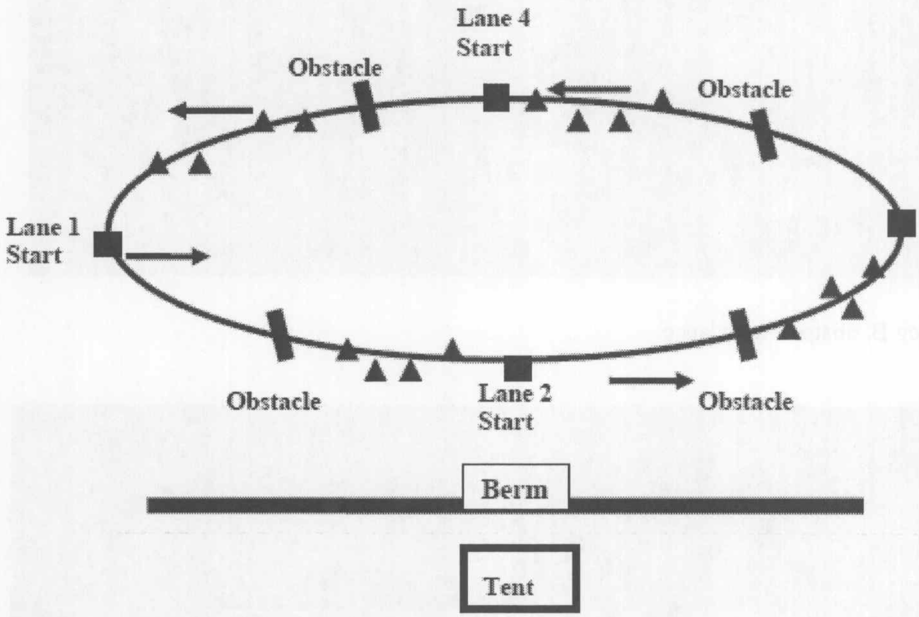

Figure 8. Robotic driving course.

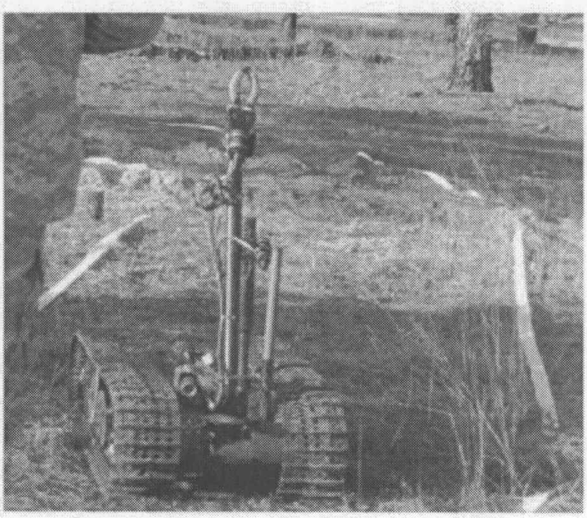

Figure 9. Leg A, maneuver.