Evaluating Accessibility and Usability of an Experimental Situational Awareness Room

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Abstract. New advanced emergency management facilities such as a control room which is equipped with advanced ICT technologies should consider universal design principles and ensure the accessibility and usability of some important technical functions available in the room. This paper aims at evaluating the accessibility and usability of an experimental control room. This room has a flexible architecture, i.e., the information displays are interchangeable through drag-drop system on a control-panel. We used a complementary heuristic and user testing approach. A video analysis, open questionnaire and discussion with testers were applied to detect technology usage barriers. The results show that the proprietary control tablet and its setup has some room for improvement. Our approach can examine the sources of difficulties of our testers, especially on linking the information sources, machines and wall or desk displays. Several recommendations are outlined to be a basis for developing guidelines for future usage of this room.

Keywords: Control Room · Situational Awareness · Universal Design · Testing · Accessibility · Usability · Heuristic Testing · User Testing

1 Introduction

There is an increasing awareness about the importance of Universal Design (UD) of Information and Communication Technology (ICT), where the goal is an inclusive digital society with as few barriers and hindrances as possible, for a broad diversity of users, including the elderly and people with disabilities, in a wide range of situations and with a diversity of equipment. While accessibility is primarily focused on disabled users being technically able to use a system; universal design takes a broader perspective, including usability for all as an important factor. Likewise, when designing a room with complex ICT equipment such as a control room, the universal design principles including accessibility and usability are becoming important.

A control room is a physical facility that is built for a specific purpose such as monitoring a process or coordinating, collaboration tasks and actions to distributed task-force, including to provide directions, orders and decisions [1]. There are various terminologies in the literature when it comes to the control room, which may be known as “command and control (C2C) center”[1], “operations center”[2], “incident command

center"[3] or "situation room"[4]. The usage of these terms varies, depending on their purposes or application areas such as military, politics, space center, meteorological satellite, emergency management, network monitoring, industrial production processes, transportation, and data centers. Typically, a control room consists of multiple displays or even wall-sized area and control panels, where operators can collect, visualize and monitor information received through its facilities, in the form of images, videos or data stream. In this paper, we use two interchangeable terms, i.e. situational awareness or control room to refer to a newly established experimental situational awareness room.

The aim of this paper is to evaluate the accessibility and usability of this experimental situational awareness room, in order to detect accessibility barriers as well as usability issues, and to propose solutions. By taking advantages of todays' multimedia technologies, this room has been designed as a flexible room for training. In a traditional control room, one operator may control 1-2 PCs. In this experimental control room architecture, with one control panel, an operator can control each available PCs in the room and visualize any information sources on any displays in the room easily through "drag and drop" technique on a single touchscreen control tablet. One operator can control and distribute up to 11 information sources simultaneously. The control room in question contains two wide multi-monitor walls (2x3 and 2x2 monitors) in addition to dual-monitor setups on each work space (see Fig. 1). Any view from the workspace monitors can be set to display on the wide monitors on the wall; either a single one or extended across 2x2 or 2x3 monitors. Any information can be swapped across the wall monitors. These views typically show visualisations simultaneously like charts or graphs, filtered twitter feeds, maps, presentations or simulations in the form of serious games, sensor readings, or live video.

Fig. 1. Sketch of Experimental Situational Awareness Room

This study is not only intended to improve the usability and accessibility and remove barriers in the control room in question, but to be able to serve as input for others in the process of establishing control rooms designated for increasing situational awareness. Our usability testing procedures can also be replicat4ed for others who want to test the usability of their facilities. Since a control room is a controlled situation with fixed equipment, two important aspects of universal design, ambient situation and technical equipment, can to some degree be optimised for the intended primary users. One of the

newly introduced features in this room is a centralized control panel that allows flexible use of all capacities in the room, including all PCs, monitors and video conference system. However, the diversity of users still may trigger potential barriers, and usability issues can easily occur in systems that are designed with a fixed set of requirements, based on needed functionality rather than a user-centred design process.

Concerning universal design, we hypothesise that typical barriers and usability issues that may occur in this type of control room include:

- Information overload. Too much information means that potentially important information will be lost.
- Too complicated user interfaces of the control panel that controls the video walls, meaning that the full potential of the equipment will not be exploited.
- Lack of keyboard equivalents for e.g. drag-and-drop or multi-touch zoom.
- Visualisations such as maps or graphs may lack an alternative representation of the data.

For performing the evaluation of the control room and indicated barriers above, several methods will be used, including heuristic testing and user testing of selected aspects of the control room, including the typical barriers and issues mentioned above.

The rest of the paper is organized as follows: Section 2 is a literature review on the design of the control room and usability testing in the control room setting. Section 3 comprises suggested method for usability test. Section 4 presents the results of the testing, followed by discussion in Section 5. The conclusions and future works are presented in Section 6.

2 Literature Review

Konskinen [5] points out that traditionally control rooms have been seen as a *place* that has been designed for certain *actors* for the *control* of some *process*. Today, there is however a pressure for change with regard to each of the main components of the above control room definition:

- *Remodelling of control room structures*. The definition of the control room has shifted from a stationary, single room space to also include mobile and spatially distributed control spaces.
- *Changes in the allocation of operative tasks*. The operator is no longer a single person but rather a team of people or, even joint automatic agents that collaborate with human actors.
- *Enlargement of the focus of the process.* The operator is no longer only thinking about present situation, but also emphasizing to consider both the past events and the expected future behaviour of the process.
- *Enlargement of the control room focus*. There is a pressure to enlarge the focus of control from operations.

It has been long known that introducing technologies of complex socio-technical networked systems pose new problems for design that require development of new methods. Design of collaboration support is described in [6], and user-centric design is very relevant here as well [7, 8].

Ecological Interface Design (EID) is an approach that is being promoted for situational awareness operators, that assists monitoring activity for system change and designing interface to decrease the cognitive burden of operators [4, 9].

Concerning computer-supported collaborative work (CSCW) in a control room, it has been argued that a focus on the collaborative social context and an ethnography approach would be beneficial in the design of the systems [10]. For our context, user centric design and CSCW would be most beneficial before the control room is built. However, this perspective is still useful for developing usage guidelines that are adapted to the user's working style.

Methods are being developed for more flexible interfaces in the control room [11], and the mobile control room operator interface [12] is also being investigated. The impact of visual information and display formats is examined in [13, 14]. Resilience through sense-making and control are discussed in [15], and the increasing use of social media for crisis mapping is the topic of [16]. There are significant challenges and obstacles in sharing information and coordinating between different agencies in an emergency, as discussed in [17]. Several of the challenges discussed in these papers are relevant for the use of our control room.

Metrics and methods for evaluating control room operator performance are described in [18, 19]. Control room quality and improvement have been evaluated through analysis of critical operator decisions [20], person-in-the-loop testing [21], and finally Boring et al. propose a framework for design process and evaluation metrics for control room modernization in [22]. However, most of these evaluations tend to focus on industrial processes which can be very different from crisis situations. Therefore, based on some common approaches to evaluating usability of environments, devices and technologies, we will adapt and suggest usability testing methods that can be considered as part of the contribution of this paper.

3 Evaluation Methodology

We will perform a two-part evaluation, based on user testing as well as a brief heuristic evaluation. The test methodology and setup will be described further in the following.

3.1 User Testing Setup

User-based testing usually involving direct participation of the testers. Users are invited to do typical tasks with a product, or simply asked to explore it freely, while their behaviours are observed and recorded in order to identify design flaws that cause user errors or difficulties. During these observations, the time required to complete a task, task completion rates, and number and types of errors, are recorded [23]. The procedure as suggested by Bastien [23] is as follows:

- *the definition of the test objectives*: testing the usability of functionalities of equipment in the ESA room.
- *the tester qualification*: users interested in multimedia will be sufficient.
- *the selection of tasks participants to realize*: the users should be able to operate the dynamic features of the room.
- *the creation and description of the task scenarios*: the tasks are listed in the script below.
- *the choice of the measures that will be made:* time to complete task (or failure).

- *as well as the way data will be recorded:* results will be recorded in a spreadsheet. Video will be recorded with the tester's permission, to catch any comments along the way and to verify timing.
- *the preparation of the test materials and of the test environment:* the initial state setup is outlined below.
- *the choice of the tester, and the design of the test protocol per se:* after a brief introduction to the system, the script outlined below will be followed, and finally the questions of the questionnaire will be asked to the user.
- *the design and/or the selection of satisfaction questionnaires:* the questions of the questionnaire are listed below.
- *the data analyses procedures to get results*: we will use the data recorded in the spreadsheet, questionnaire responses as well as video analysis, to discover and highlight the barriers and usability issues discovered during the testing.

Initial State Setup. The initial state is based on the following scenario: mastering the usage of the control panel equipment that will control information distribution on the wall screens and PC input and output control on the table. The testing is divided into two parts: 1) understanding the use and change the PCs controlled by the table, and 2) the usage of functionality to present multiple information on the wall screens.

The PCs on the table is set up as shown in Table 1. Any of the PCs can be used on either the left or right side of the table, but a PC can only be controlled by one operator at a time, and the operator can only control one PC at a time.

Table 1. PCs for Desktop Operator

Left Table		**Right Table**	
Desk Monitor 1	Desk Monitor 2	Desk Monitor 1	Desk Monitor 2
PC 1	PC4	PC 1	PC4
PC 2	PC5	PC 2	PC5
PC 3	PC6	PC 3	PC6

Each side of the table has a mouse and keyboard and two monitors. The control tablet allows to control on of the PC which in turn provides from 2 to 4 Sources (outputs) that can be displayed on the different monitors on the table as well as the wall screens. We have illustrated the setup of the wall screens (1-10) as seen in Fig. 2.

Screen 1	Screen 3	Screen 5		Screen 7	Screen 9
Screen 2	Screen 4	Screen 6		Screen 8	Screen 10

Fig. 2. Video Wall Layout

The following sources have been pre-set to be initially shown on the wall screens:

- Screen 1: Ushahidi Syria Tracker (source6)
- Screen 2: #onemilliontweetmap (source12)
- Screen 3: Earthquake forecasting and prediction (source3)
- Screen 4: Emergency 2.0 Wiki (source5)
- Screen 5: yr.no wind map (source11)
- Screen 6: GDASC (source14)
- Screen 7: Lightningmaps.org (source13)
- Screen 8: NVE Flood Map (source4)
- Screen9-10: Unassigned

The control tablet is a proprietary product, it is a touch-screen based tablet device with tabs for controlling wall screens, desktop PC control, videoconference (not tested), etc. On the two control panel interfaces that were used in the test, gestures like swipe, press, press-and-hold, and drag-and-drop are used extensively to assign and control resources. No alternatives to these touchscreen gestures are provided, and no alternative input or assistive technologies can be assigned to the control panel.

The testers are three persons with solid ICT and Multimedia background, 1 male and 2 female. We will call them Tester1, Tester2, Tester3 or in short T1, T2 and T3. Testers 1-2 are not at all familiar with the setup, while Tester 3 has briefly observed it in use before, but never used it actively. Tester 3 also had the advantage of being able to observe Testers 1 and 2 in the first round.

The testers will first get a brief explanation of the equipment before the start of the test. Then two of them will take the left and right seats at the desk, while the third is free. There will be a map showing which monitors belong to which PCs on the table available to both active testers, and also a list showing the naming of the screens and the initially setup web-sites visible on each screen.

After going through the script a first time with some guidance if needed, they rotate so each person will perform both the left and right side scripts. In the second round, they are expected to manage without assistance. The partial repetition is intended to see if it is significantly easier to use with some previous experience.

Script. The following script will be used.

1) Table part introduction
    a) Left Table: Press local desk, select PC3, examine map of sources, to determine which sources are connected to PC3.
    Right Table: Press local desk, select PC2, examine map of sources, to determine which sources are connected to PC2.
    b) Check on monitor if the correct sources are displayed on the desk monitors.
    c) You can scroll sources to the left and right, select them and drag and drop to desk monitors. See what happens if you put source11 and source12 on your monitors. Can you control them? Do you know why/why not?
2) Wall screen introduction
    a) Left: Move focus to Screen 1 – which PC controls the source on screen 1?
    Right: Move focus to Screen 4 – which PC controls the source on screen 4?
    b) Both: Select that PC on your desk, and optionally put the source on one of your desk screens.
    c) Open a new tab in the browser (you may need to press F11 to exit full screen).

d) Open local weather forecast (www.yr.no)

3) You expect a thunder storm and want to monitor weather-related sites.
   a) Left: Move source of Screen 7 to Screen 1
      Right: Move source of screen 8 to screen 9
   b) Left: Expand Screen 1 (Weather forecast) to cover 2x2 across screens 1-4 (press and hold).
      Right: Expand Screen 9 to cover 2x2 across screens 7-10 (press and hold).
4) Left side: You need more information.
      Check if there are any recent (last 30 minutes) tweets mentioning thunderstorms in Norway (how do you get back twitter to Screen 2?)
   Right side: Earthquake reported on the west coast of Sri Lanka.
      Open/retrieve QuakeWatch (originally on Screen 3) to Screens 7-10 (2x2)
5) There was an earthquake strong enough to potentially trigger a tsunami
   a) Left side: Open https://tsunami.gov in a suitable screen.
      Right side: Check for related tsunami warnings using twitter on Screen 2.

Evaluation Questionnaire. The following questions will be asked to the participants after finishing the test.

- Did you feel information overload at any time during this test?
- Was any of the user interfaces very/too complicated to use/understand?
- Which subtask was most difficult?
- Which subtask was easiest?
- Was it much easier in the second round?
- Any other comments or suggestions?

3.2 Heuristic Evaluation of Selected User Interfaces

The heuristic evaluation will focus primarily on the control tablet, it may be a usability bottleneck since it is a fixed proprietary piece of equipment, while the software running on the different screens can be adapted at will. The potential issues mentioned in Section 1 will in particular be noted. Jakob Nielsen has defined a set of 10 usability heuristics for user interface design [24] that we adopt as our main heuristics, and in addition, we will search for accessibility issues from the perspective of personas [25], imaginary users representing diverse user groups:

- John (55), blind. Experienced computer user with diverse assistive technologies.
- Linda (25). Experienced computer user, used to (fixed) multiple monitor setups.
- Tom (33), motoric disability affecting dexterity of hands. Uses switch control as assistive technology.
- Rita (42), hard of hearing. Uses sign language interpreter for communication.
- Fred (29), mild cognitive disability. Have some experience with computing, but easily overwhelmed by too complex systems.

To facilitate the heuristic evaluation, we will perform tasks from the user testing script.

4 Results

In the following, we will present the results of the tests that were performed, first the results of the user testing, then the heuristics testing.

4.1 User Testing

The results of running the user tests are shown in Table 2. The column titles consist of set of tasks and sub-tasks no. 1-5 as explained in Section 3. The testers are listed in the first column, while the second column shows if the testers were in the first, second or third round, and in which table (Left -L or Right -R). We see that there is a clear progress from the first to the second round in all testers even if the tasks are slightly different between the right and left side scripts. While some of the testers needed some assistance in the first round, this was not needed in later rounds. The feedback from the testers also confirmed that the system has an initial learning curve but is relatively easy to operate after the initial confusion is overcome. Note that there was an error in the equipment not allowing the enlargement across screens (used in task 3b) to be performed after the first round.

Table 2. Results

Tester	Round/ Place	1a	1b	1c	2a	2b	2c	2d	3a	3b	4	5	Total
T1	1/L	15s	35s	20s	1m 55s	30s	30s	15s	55s	35s	2m 35s	1m 5s	12m 30s
T1	3/R	10s	15s	35s	15s	15s	1m 30s	5s	10s	Err	30s	55s	7m 20s
T2	1/R	22s	3m	1m 8s	1m 55s	55s	20s	20s	1min 45s	1min 30s	2m	2m 30s	15m 40s
T2	2/L	15s	40s	30s	15s	15s	1m 20s	5s	10s	Err	10s	35s	6m 30s
T3	2/R	25s	35s	25s	40s	35s	2m 20s	10s	15s	Err	1m 50s	30s	8m 30s
T3	3/L	10s	15s	35s	10s	10s	50s	5s	10s	Err	25s	15s	5m 40s

After two series of the operational testing, we conducted an intensive discussion (video recorded, annotated). The results are as follow:

On the information overload: we posed questions whether the testers felt information overload during the testing. Apparently, there was no such information overload issue among the testers, but rather the barrier issue when using multiple information sources. In other words, they consider it was manageable. But in testing, there was no crisis situation so that we can also say that the testing results are limited to "experimental setting" rather than real crisis situation. While the sources of barriers mostly come from not knowing which sources come from which PCs and visualize in which screens.

On complexity of the user interface: we discussed whether or not the user interface of the display system and operator desk was too complicated to use/understand. All the testers agreed that it was not a problem when one had got to know how the system

worked. The confusion on relationship between sources, screens and which PCs to control was mentioned again.

On the most difficult task: (please also refer to our script for the task descriptions): It was mentioned that 3b was difficult because the press-and-hold gesture was a bit difficult to do correctly, an did not work correctly after the first round. In addition, it was pointed out that 5A right: «check for related...» had difficult to understand instructions, and since sources had been moved around in the meantime, the website was not where expected.

On the easiest task: it was agreed that opening a website in a new tab (2c-d) was very easy, and also swapping sources between screens (3a) was very easy.

On the second round: all testers agreed that the second round was easier or much easier. On of the testers also found the first round to be relatively easy too, except for the confusion concerning sources, screens and PCs. They all agreed that if working regularly with the equipment, it would be easy. It was also mentioned that if two people were working together regularly, they will want to split the resources between them.

Other comments or recommendations: The confusion concerning sources, screens and PCs could be mitigated by renaming sources, use logical naming convention, and all it output instead of the current naming, to avoid confusion e.g. PC1-Output1, PC1-Output2, PC2-Output1. It was also suggested to add an always on top ID-note in the corner of each source, showing which source is on which screen. In addition, it would be good to be able to automatically change sources on desktop monitors to the PC you control. Concerning user interactions, it was recommended to enable the use of two touchscreen presses as Select and Apply as an alternative to drag-and-drop. One tester would also like to see an overview display on the control panel, allowing to see video wall layout while controlling the desktop PCs. It was finally suggested to have a separate preview screen showing a grid of all active Sources next to the two main desk screens, to mitigate the first-row-in-cinema effect having to bend the neck backwards to look up at the top wall screens.

4.2 Heuristic Testing

The heuristic testing in particular focused on the control panel user interface, as this turns out to be an important element of the dynamic use of the control room.
From the perspective of Nielsen's 10 heuristics, the following issues were found:

- *User control and freedom:* No undo available. However, actions are reversible.
- *Consistency and standards:* Inconsistent behavior concerning desktop control not automatically providing (or preselecting) the Sources (graphical outputs) belonging to the PC that is controlled, and no connection between PCs and Sources except for an external map printed on paper.
- *Error prevention:* Limited functionality means limited opportunity for creating error situations.
- *Recognition rather than recall:* User needs to remember which Sources belongs to which PC.
- *Flexibility and efficiency of use:* Allows saving and recalling commonly used presets. No alternative ways to perform commonly used actions.
- *Aesthetic and minimalist design: Yes*

- *Help users recognize, diagnose, and recover from errors:* No error message observed during error.
- *Help and documentation:* Not available.

Most of the personas and in particular the ones with disabilities may face minor or major barriers, particularly in the interaction with the control tablet.

- *John (55), blind. Experienced computer user with diverse assistive technologies.*
    - Main barrier: control tablet. No voice output, no way to attach AT.
    - Several of the web sites used as part of the information stream are not accessible, because of lack of alternative presentation for visualizations and maps, and other issues as detailed in [26].
- *Linda (25). Experienced computer user, used to (fixed) multiple monitor setups.*
    - No obvious barriers.
- *Tom (33), motoric disability affecting dexterity of hands. Uses switch control as assistive technology.*
    - Main barrier: control tablet drag-and-drop with no alternative way to control the system.
- *Rita (42), hard of hearing. Uses sign language interpreter for communication.*
    - Main barrier: verbal communication with other operators.
- *Fred (29), mild cognitive disability. Have some experience with computers, but easily overwhelmed by too complex systems.*
    - Main barriers: Risk of information overload.

4.3 Recommendations

Based on the input from the user testing and the heuristic evaluation, the following recommendations are highlighted.

- Introduce a naming convention for Sources making it clear which PC each source belongs to, e.g. *PC1-Output1, PC1-Output2, PC2-Output1*.
- Always-on-top ID information in corner of each Source desktop to make it easy to see which PC/Source any given view belongs to.
- The next generation control tablet should allow connection of mouse/keyboard and assistive technologies for more flexible control methods.
- The next generation control tablet should allow other methods of assigning sources using the touchscreen than drag-and-drop, such as select-and-apply (press-to-select, press again to assign).
- Make sure that the different visualizations and maps that form part of the information stream are accessible to all potential users.

5 Discussions

Since we only had a quite small number of test users (three), and the heuristic evaluation was primarily focused on the control tablet, we cannot claim to have discovered all barriers and usability issues. However, the testers were highly motivated and also provided several very useful comments and suggestions in the free discussion following the questionnaire questions.

We intentionally had two test users active at a time to highlight the collaborative aspects as well as potential competing for resources. However, timing was not so accurate since the testers often forgot to say when they had finished a task, and sometimes delay was caused by waiting for access to the control panel or competing for controlling sources from the same PC.

6 Conclusions and Future Works

The user testing as well as the heuristic evaluation has provided us with a good set of recommendations that will enable the improvement of the control room usability significantly, lowering the threshold of entry for new operators. Not all issues can be solved immediately, as the proprietary software of the control tablet is out of our hands, but the issues will still be noted and worked around as far as possible – and noted as requirements for future upgrades. It was also encouraging that the testers found it easy to perform the test tasks in the second round. The testers also found it enjoyable and interesting to test the control room, and were very positive concerning its potential for training, experiments and research on future directions in situational awareness technology. This is a great opportunity to nudge tomorrow's control rooms towards more focus on inclusive design, usability and accessibility.

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