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Usability Study of Two Collocated Prototype System Displays

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Abstract

Currently, most of the displays in control rooms can be categorized as status screens, alerts/procedures screens (or paper), or control screens (where the state of a component is changed by the operator). The primary focus of this line of research is to determine which pieces of information (status, alerts/procedures, and control) should be collocated. Two collocated displays were tested for ease of understanding in an automated desktop survey. This usability study was conducted as a prelude to a larger human-in-the-loop experiment in order to verify that the 2 new collocated displays were easy to learn and usable. The results indicate that while the Dial-on-Control display was preferred and yielded better performance than the Multi-Dimensional Object display, both collocated displays can be easily learned and used.

Introduction

Currently, most of the displays in control rooms can be categorized as status screens, alerts/procedures screens (or paper), or control screens (where the state of a component is changed by the operator). With the advent and use of graphical displays and various types of input devices, and the associated computing power available to compute and display information, it is now possible to combine these different elements of information and control onto a single display. The primary focus of the present research is whether these pieces of information (status, alerts/procedures, and control) should be collocated.

Previous research found that operators like to have status, alerts and procedures, and controls located on the same screen or have status and alerts and procedures on one display with controls on another (Bartolone & Trujillo, 2002, p. 2; Trujillo, 2001a, 2001b). This research was done with displays that were not specifically designed for collocation. A follow-on experiment was planned to test two displays specifically designed for collocation.

Before the follow-on experiment was run, the collocated displays were tested for ease of understanding by way of an automated desktop survey. This pre-test was conducted to ensure that the two newly designed collocated displays were intuitive enough such that the general untrained population could begin using and understanding them with just a brief introduction to them.

Objectives

This experiment was conducted to attest that subjects could quickly and easily understand the two new collocated displays. In order to fully meet the objectives, three independent variables were varied. These independent variables were (1) display format, (2) parameter repetition, and (3) display order.

For display format, each subject saw the baseline display and one of the collocated displays. The collocated displays were the dial-on-control (DC) and multi-dimensional object (MDO) display formats.

Parameter repetition and display order were manipulated in order to satisfy the objective that the display formats were quickly and easily understood. Parameter repetition referred to the number of times each subject saw a particular non-normal parameter (pressure, temperature, and quantity). Display order referred to the order subjects saw the baseline display and the collocated display.

Display Format

Each subject saw two display formats: (1) standard status displays and controls (baseline) and (2) one of the collocated displays – dial-on-control or multi-dimensional object. All the display formats modeled the same system.

The system modeled was generic and consisted of a tank (TANK) that fed two pumps (L PUMP and R PUMP) whose combined output was shown with overall system parameters (SYS) (Fig. 1). The parameters associated with each component and their alert levels are shown in table 1. For this study, warning alerts were red in color, cautions were amber, and advisories were cyan. Normal values, which comprised the remaining instrument range, were shown in green.

Baseline

The baseline display format presented the status information separate from the control screen. Status information was represented with standard dial formats (Fig. 2). When all the parameters were at their expected values, the dial pointers were horizontal. A decreasing value was indicated with the dial pointer rotating counter-clockwise while an increasing value was indicated with the dial pointer rotating clockwise. This aspect of the display encouraged check reading because pattern matching could be employed; any parameter deviation had a dial pointer departing from horizontal (Sanders & McCormick, 1987, pp. 128-129).

The control screen duplicated the functional layout of the generic system (Fig. 2). Components that had no change of state, in this case the tank and system information, were shown with white squares. Components that could change state (*i.e.*, turn "on" and "off"), such as the left and right pumps, were represented with circles. A single outlined circle indicated a component was "on" while a double circle denoted a component was "off." The outline color of the component announced the highest alert range the component's parameters had reached. In other words, if the left pump's pressure was in the warning range and temperature was in the caution range, the component outline was red for warning. A "failed" component was shown with a red outline and a red X across the component.

Collocated Displays

The collocated displays were designed so that all three types of information were located on one screen (Bartolone & Trujillo, 2002; Mahaffey, Horst, & Munson, 1986, p. 1514; Trujillo, 2001a, 2001b) and judiciously used color in order to enhance the displays (Stokes, Wickens, & Kite, 1990, pp. 65-87). Both were pictorial in format, which suggested less processing would be required (Weinstein & Wickens, 1992, p. 137) especially if patterns could be learned and discerned (Stokes, Wickens, & Kite, 1990, p. 9). Furthermore, the information in a single location could enhance emergent features (Buttigieg & Sanderson, 1991, p. 647) and increase the likelihood of noticing a non-normal situation developing (Davis, 2004, p. 2).

Dial-on-Control (DC). The dial-on-control format was a collocated display with the parameter information integrated into the control display (Fig. 3). This display shared some of the conventions employed in the baseline display. Components with no change of state were depicted as square while components that could change state were depicted as circles. Also, a single outlined circle indicated a component was "on" while a double circle designated a component was "off."

Each component symbol was split in half vertically. The left half of the component symbol registered either pressure or quantity while the right half of the component symbol indicated temperature. Pressure was shown with a triangle icon, quantity with a rectangle, and temperature with a circle. The icons traveled around the component outline. As a parameter increased, the icon rose and as a parameter decreased, the icon fell. When all the parameters were at their expected values, the icons were at the horizontal middle of the component outline. Therefore, this display incorporated both collocation and limited pattern matching.

The appropriately color-coded alert range was indicated at either the top or bottom of the component outline. For example, the tank's low quantity warning was shown on the lower part of the left-half of the tank outline and the tank's high temperature advisory was shown on the upper part of the right-half of the tank outline. The rest of the component outline was green, except for the alert ranges.

If a parameter reached an alert range, the icon changed from white to black and the component name was in the same color as the highest classification that the component's parameters were in; otherwise the component's name was in white. A "failed" component had a red X through the component and the component's name was in red, which indicated a warning.

Multi-Dimensional Object (MDO). As with the DC display, the MDO display collocated the parameter information with the control display but the parameter information was more integrated pictorially into the control display (similar to Albert et al., 2003); therefore, this display supported collocation with no pattern matching because subjects were unfamiliar with this display (Fig. 4). The additional incorporation of the parameter information was thought to enhance visual processing of the display in a glance such as was found with polar-star displays (Bartolone & Trujillo, 2002; Mahaffey, Horst, & Munson, 1986; Trujillo, 2002, 2004). As with the other two displays, components with no change of state were square while components that could change state were circles. For the components with a change of state (*i.e.*, turn "on" and "off"), a solid white outline indicated a component that was "on" while a dotted white outline indicated a component that was "off." A "failed" component had a red X through it.

Pressure was indicated by size. If pressure increased, the colored component fill grew proportionally (Fig. 5). If pressure decreased, the colored fill shrank proportionally. The beginning of a pressure alert range was shown with a dotted colored outline indicating the alert level (red, amber, or cyan). If the pressure alert range was reached, the dotted colored outline went solid.

Temperature was indicated by fill color (Fig. 6). If the temperature increased, the fill color changed from green to the alert range color from the center out. If the temperature decreased, the fill color changed from green to the alert range color from the outside in. The beginning of the high temperature alert range was indicated by the outside edge of the colored component fill and the beginning of a low temperature alert range was indicated by the center of the colored component fill. If a high temperature alert were reached, the fill color was the same as the alert range color with a dotted green outline at the edge. If a low temperature alert range were reached, the fill color was the same as the alert range color with a small black circle in the middle.

Quantity was indicated by fill level (Fig. 7). The fill level would rise if the quantity increased and the fill level would fall if the quantity decreased. Normal fill level was indicated by a small white horizontal line on the side of the component outline. The beginning of an alert range was shown by a small color coded line on the side of the component outline. When an alert range was reached, the component name turned black and the top of the fill level changed to the color coded alert range.

Hypotheses

The general hypothesis was that the two new collocated displays would not be significantly different from the baseline display with respect to operator understanding of the displays and preference. The specific hypotheses are below.

When considering the display types, the following statements hold true:

1. When choosing the component affected, the direction of parameter movement or the alert level of a parameter, there will be no accuracy difference among the three displays.

2. When choosing the parameter affected, there will be no accuracy difference between the baseline display and the DC display but there will be a small decrease in accuracy for the MDO display from the baseline display.

3. Subjects will be able to discern the state of the component (*i.e.*, “on,” “off” or “failed,” and changeable or static), the component affected, the parameter affected, the direction of parameter movement, and the alert level with the minimal training provided.

4. Subjects will have no preference between the baseline display and the DC display but they will have a preference for the baseline display over the MDO display.

5. Workload will be no different between the baseline display and the two collocated displays.

6. Subjects will indicate the ease of determining the component affected, the parameter affected, the direction of parameter movement, the alert level, and the overall ease of use for the two collocated displays to be equal to the baseline display.

When considering the order, the following statement holds true:

7. There will be no significant difference between the order the subjects saw the displays.

Experiment Design

Subjects

Ten people participated as subjects. Four were female and 6 were male, and 2 were certificated pilots (1 female and 1 male). All used computers for work and were familiar with flight decks and flight procedures even if they were not certificated pilots.

Test Design

The experiment was conducted on a PC using an HTML interface. The HTML code was hosted on an SGI® IRIX® machine acting as the web server, which used Netscape© Administration web server software version 2.13. The HTML code was programmed in PERL version 5.6.1.

Each subject saw the baseline display and one of the collocated display formats. Four subjects saw the baseline display first and then the collocated display (2 baseline then DC and 2 baseline then MDO) while the rest of the subjects saw the collocated display first and then the baseline display (3 DC then baseline and 3 MDO then baseline).

Component and parameter order was randomized by subject. In general, each subject had 15 non-normal conditions for the left pump, 14 non-normal conditions each for the right pump and tank, and 7 non-normal conditions for the system. Subjects also had 20 non-normal conditions involving pressure, 6 non-normal conditions involving quantity, and 24 non-normal conditions involving temperature.

Each subject answered 15 questions per display type about the symbology and 25 questions about a non-normal condition they saw per dial type. This resulted in the study lasting 40– 60 minutes per subject.

Dependent Variables

The dependent variables consisted of the subjects’ answers to the questions. The objective questions asked and the answer choices are listed in Table 2.

At the end of each display format, subjects completed the NASA-TLX workload measure questionnaire (Byers, Bittner, & Hill, 1989; Hart & Staveland, 1988). Each of the individual factors that constitute the NASA-TLX (mental, physical, and temporal demand; performance; effort; and frustration level) was rated on a scale with nine equal graduations.

Next, subjects indicated how difficult it was to determine the non-normal situation (Questions 1 – 5). At the end of the test, subjects answered questions comparing the collocated display to the baseline display (Questions 6 – 9). Lastly, subjects answered questions about their preferences for the collocated displays (Questions 10 – 11). Table 3 details the questions.

Procedure

When subjects first arrived, they filled out an informed consent form (Appendix A). They were then briefed on the hardware and software setup. Subjects used a right-handed mouse and the web-interface was shown on a 53.34 cm (21”) (50.292 cm (19.8”) visible) diagonal Sony Trinitron™ flat screen. Display resolution was 1280 x 1024 pixels with a 32 bit color quality.

Each display description was self paced. Subjects first read a description about the display format they would be seeing. They then answered questions 1 – 4 from Table 2 for each of the parameters (pressure, temperature, and quantity).

Once the subjects answered the above questions correctly, they then read directions about the next phase of the task. During this phase, a picture was displayed for 3 sec. On the picture was a component with a single parameter deviating from normal (Fig. 8). After 3 sec, the display was replaced with questions 5 – 7 from Table 2. Each subject had 25 pictures for each display format.

After the subjects answered the questions for timed a display format, they completed the NASA-TLX and indicated how difficult it was to determine the non-normal situation.

Next, the display format description for the second display seen was presented and the above process was repeated.

Lastly, subjects answered the questions comparing the collocated display to the baseline display and their overall preferences.

Data Analysis

Data was analyzed using SPSS® v13.0, Statistical Product and Service Solutions (SPSS Inc., 2004). The data was analyzed using a χ^2 test except for parameter repetition which was analyzed using a 1-way ANOVA. In all cases, statistical significance was set at $p \leq 0.05$.

Results and Discussion

Accuracy in Identifying Affected Characteristic

Component

Display format was significant (χ^2 (2)=9.89, $p<0.01$) for determining which component (tank, left pump, right pump, system) had the non-normal value. Subjects using the MDO display format were 92% accurate in determining the component that was not normal as compared to the baseline and DC display formats, 99% and 97% accuracy respectively.

Parameter

Display format and display order were significant ($\chi^2(2)=25.02$, $p<0.01$ and χ^2 (3)=15.70, $p<0.01$ respectively) for determining which component parameter (pressure, temperature, quantity) was affected. Subjects using the MDO display format were 85% accurate in determining the component parameter that was not normal as compared to the baseline and DC display formats, 98% accurate and 94% respectively. Although not significant, temperature caused the most problems, especially for the MDO display

(Figure 9). Also, subjects were correct the least often when they saw the MDO display first and then saw the baseline display. See table 4 for a detailed breakdown.

Direction

Display format ($\chi^2(2)=43.62$, $p<0.01$), display order ($\chi^2(3)=16.70$, $p<0.01$), and parameter repetition ($F(11)=1.92$, $p<0.04$) were significant for determining which direction the non-normal parameter was moving. Subjects using the MDO display format were correct in determining if the component was high or low only 81% as compared to 98% and 96% for the baseline and DC display formats. Subjects were best at determining the direction when they saw the DC display first (Table 5). As for repetition, the first two had an accuracy level of 85% while the other ten repetitions had an accuracy level above 90%.

Alert Level

Display format and the order of the display formats were significant ($\chi^2(2)=96.13$, $p<0.01$ and $\chi^2(3)=43.83$ $p<0.01$ respectively). For display format, subjects were only accurate with the alert level 66% of the time for the MDO display format as compared to 98% and 97% accurate with the baseline and DC display formats respectively. Subjects were correct the least often when they saw the MDO display format first (Table 6).

Overall Correctness of Answer

The overall correctness of each subject's answer was rated by the following: 4 for answering the correct component, parameter, direction, and alert; 3 for answering the correct component, parameter, and direction; 2 for answering the correct component and parameter; 1 for answering the correct component; and 0 for not answering anything correctly.

Display and the order seen were significant ($\chi^2(2)=107.72$, $p<0.01$ and $\chi^2(3)=49.62$, $p<0.01$ respectively). The MDO display had the lowest level of correctness (Figure 10 and Table 7). The biggest drop in correctness was seen when the MDO display was seen first (Figure 11 and Table 7). The most accurate recollection of the non-normal situation occurred when subjects saw the DC display first.

Training

Display format and display order were significant in determining whether a parameter was high, low, or in an alert range during training ($\chi^2(2)=9.72$, $p<0.01$ and $\chi^2(2)=8.08$, $p<0.05$ respectively). For display format, subjects primarily had trouble with the MDO display for determining an alert (Figure 12 and Table 8). One subject had difficulty determining a high pressure with the MDO display. For determining an alert, subjects had difficulty determining a pressure alert for the DC and baseline display (1 incorrect answer for each), and temperature (3 incorrect answers) and quantity (1 incorrect answer) alerts for the MDO display. For display order, seeing the DC or MDO display first had the most errors (Figure 13 and Table 8).

Subjective Data

Workload

There was no statistically significant difference in workload across the three displays. Therefore, this suggests that subjects perceived that the 2 collocated displays did not add additional workload although the MDO display did have a slightly higher workload than the other two displays (Figure 14).

Ease

There was no statistically significant difference between their ratings of how easy or difficult they thought it was to determine the component and parameter affected, whether it was high, low or in an alert range, the type of alert, and determining the overall state of the affected component by display type. A trend for determining if the parameter was high, low, or in an alert range was present for the displays (χ^2 (2)=5.76, p<0.06). The MDO display had a higher difficulty rating than the baseline and DC displays (Figure 15).

Compare

There was no statistically significant difference for dial preference. A large difference between preferences for DC and MDO displays when compared to the baseline display was seen but was not statistically significant due to a small sample size and the standard deviation (Figure 16).

Concluding Remarks

This usability study was conducted as a prelude to a larger human-in-the-loop experiment in order to verify that the 2 new collocated displays were easy to learn and usable. This objective was accomplished by conducting a brief training period followed by several runs where subjects had to remember a single-point failure after looking at a static display for five seconds.

The better performance for the baseline and DC displays is not unexpected. The baseline display setup is familiar to most people. The DC display incorporated several aspects of the baseline display into it; dial-like parameter readings were still available, which enhanced the pattern matching aspect of the display for detecting non-normal situations (Jones, Wickens, & Deutsch, 1990, p. 2; Sanders & McCormick, 1987, pp. 128-129). Also, the amount of perceptual information of the two displays were about the same so there may have been no detriment associated with attending to separated displays as opposed to looking at only one object (Davis, 2004, p. 5)

Furthermore, this task was essentially a detect and diagnose task. The dial-type formats of the baseline and DC displays may have facilitated this task because effective diagnosis may require separate displays, in this case separate dials. This may be because attention must be paid to each cue in order to make the proper diagnosis (Jones, Wickens, & Deutsch, 1990, p. 2). To further aid in the detection of these pertinent parameters, other research has suggested that less integrated displays may be of benefit (Davis, 2004, p. 15). In any case, a change from the expected normal slows detection. Recognition of the non-normal situation requires more processing to be done (Hawkins & Blakeslee, 2004, p. 167) because an operator's expectation no longer matches what he sees (Hawkins & Blakeslee, 2004, p. 88).

On the other hand, the two collocated displays, DC and MDO, showed no statistically significant differences to the baseline display subjectively. The perceived workload was the same for all displays. The MDO display's performance decrement appeared when subjects had to detail which way the parameter was moving and its alert level, suggesting the MDO display required more processing (Stokes & Wickens, 1988, p. 414). No preference was indicated for the displays even though other research has shown that subjects prefer integrated displays (Jones, Wickens, & Deutsch, 1990, p. 13). For relatively stable displays, *i.e.*, displays that do not change often, some type of collocation may be beneficial because of same-object benefits (Davis, 2004).

It is unclear whether collocation or pattern matching is driving the performance differences. Detecting a change from a typically stable condition suggests that collocation would be of benefit along with some type of pattern matching. This would indicate that the DC display should have shown superior performance because the information is more collocated with pattern matching available but with easy to discern parameter directional movement.

In any case, the results indicate that while the MDO display is not as well liked or as good as the DC display, both collocated displays can be easily learned and used. The primary problem with the MDO display seems to be in determining whether a parameter is high or low, and the alert level. This aspect has to be learned because, unlike the other two displays, the up and down direction does not indicate high and low and the alert range is not located at the top or bottom of the display. Therefore, a more realistic experiment using these three displays will be conducted in order to better determine the benefits of each type of display.

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Tables

Table 1. System Components with Their Parameters and Alert Levels

Component and Parameter	Alert Level
Tank	
Temperature	Advisory (high)
Quantity	Warning (low)
Left Pump	
Pressure	Warning (high)
Temperature	Caution (high)
Right Pump	
Pressure	Caution (high)
Temperature	Advisory (high)
System	
Pressure	Warning (high) Advisory (low)
Temperature	Caution (high)

Table 2. Objective Experiment Questions and Answer Choices

Question	Answer Choices
1. This picture indicates a component that	• Can change state (i.e., on & off) • Can NOT change state
2. This picture indicates a component that is	• On • Off • Failed
3. This picture indicates what type of parameter?	• Pressure • Temperature • Quantity
4. This picture indicates a parameter that is	• High • Low • Alert
5. Which component is non-normal?	• System • Left Pump • Right Pump • Tank • Don't Know
6. Which parameter is non-normal?	• Pressure • Temperature • Quantity • Don't Know
7. The non-normal parameter is?	• High • Low • Don't Know • No Alert • Advisory • Caution • Warning • Don't Know

Table 3. Subjective Experiment Questions and Answer Choices

Question	Answer Choice Range (9 equal graduations)
1. To determine the component (System, Left Pump, Right Pump, Tank) affected is …	Very Easy to Very Hard
2. To determine the parameter (Pressure, Temperature, Quantity) affected is …	Very Easy to Very Hard
3. To determine the direction (Low, High) is …	Very Easy to Very Hard
4. To determine the alert level (No Alert, Advisory, Caution, Warning) is …	Very Easy to Very Hard
5. To determine the overall system state is …	Very Easy to Very Hard
6. Compared to the standard dial display, to determine the component (System, Left Pump, Right Pump, Tank) affected for the [collocated display] is ...	Easier to Harder
7. Compared to the standard dial display, to determine the parameter (Pressure, Temperature, Quantity) affected for the [collocated] display is ...	Easier to Harder
8. Compared to the standard dial display, to determine the direction (Low, High) affected for the [collocated] display is ...	Easier to Harder
9. Compared to the standard dial display, to determine the alert level (No Alert, Advisory, Caution, Warning) affected for the [collocated] display is ...	Easier to Harder
10. My overall preference for the Standard Dial display is …	Much Less Preferred to Much More Preferred
11. My overall preference for the [collocated] display is …	Much Less Preferred to Much More Preferred

Table 4. Percent Correct on Identifying Non-Normal Parameter

Display	Percent Correct
Baseline	98
DC	94
MDO	85
Display Order	
Beseline then DC	93
Baseline then MDO	96
DC then Baseling	99
MDO then Baseline	88

Table 5. Percent Correct on Identifying Non-Normal Parameter Direction

Display	Percent Correct
Baseline	98
DC	96
MDO	81
Display Order	
Beseline then DC	91
Baseline then MDO	88
DC then Baseling	100
MDO then Baseline	92

Table 6. Percent Correct on Identifying Non-Normal Parameter Alert

Display	Percent Correct
Baseline	98
DC	97
MDO	66
Display Order	
Standard then DC	93
Standard then MDO	89
DC then Standard	100
MDO then Standard	77

Table 7. Percent Correct on Level of Correctness

Display	Percent Correct				
	Totally Incorrect	Component Correct	Comp & Param Correct	Comp, Param, Dir Correct	Totally Correct
Baseline	2	1	1	1	94
DC	3	2	1	0	94
MDO	9	10	9	18	54
Display Order					
Standard then DC	5	2	4	1	88
Standard then MDO	6	0	8	5	81
DC then Standard	1	1	0	0	99
MDO then Standard	6	10	2	13	69

Table 8. Percent Correct on Parameter Direction During Training

Display	Percent Correct		
	Low	High	Alert
Baseline	100	100	97
DC	100	100	94
MDO	100	88	79
Display Order			
Standard then DC	100	100	100
Standard then MDO	100	100	100
DC then Standard	100	100	90
MDO then Standard	100	90	82

Figures

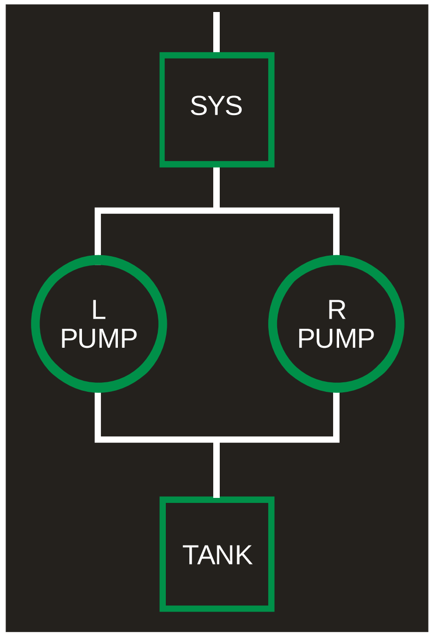

Figure 1. Generic System

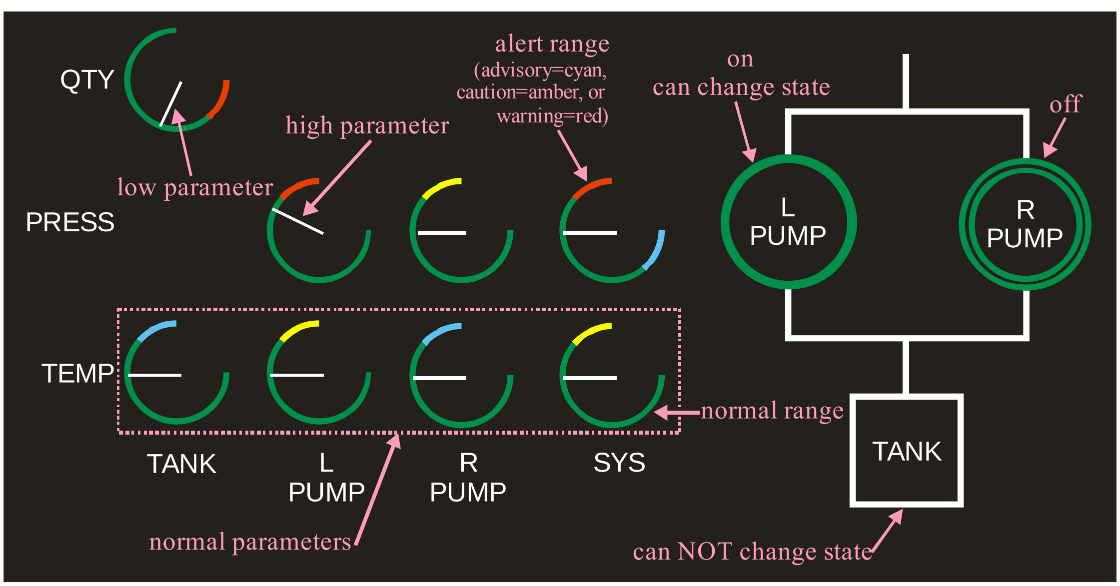

Figure 2. Baseline Display

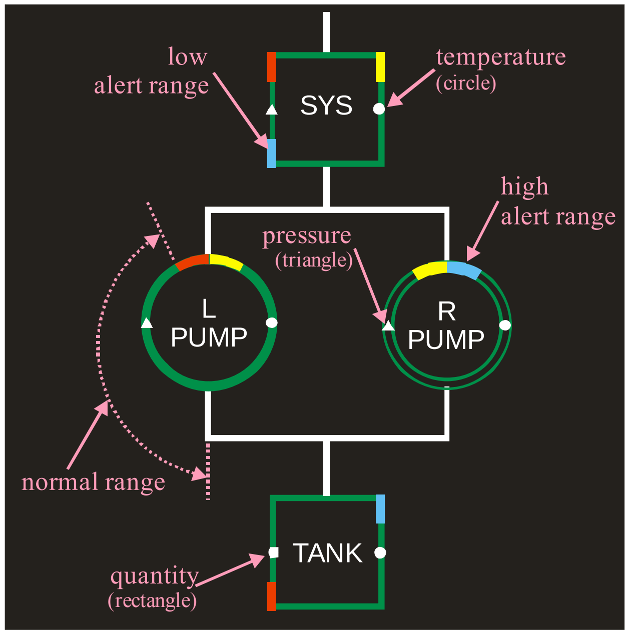

Figure 3. Dial-on-Control Display

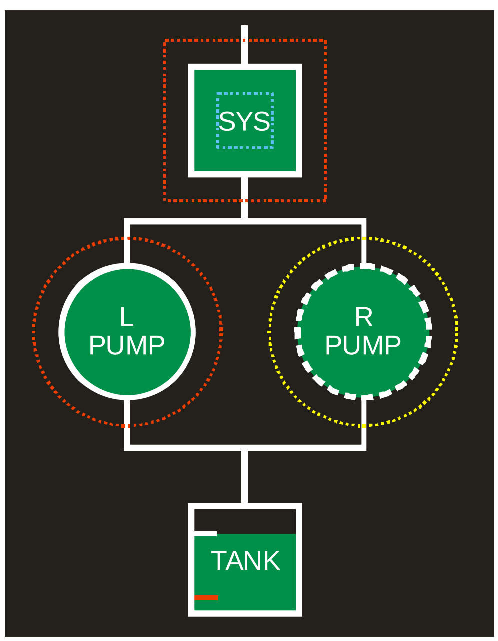

Figure 4. Multi-Dimensional Object Display

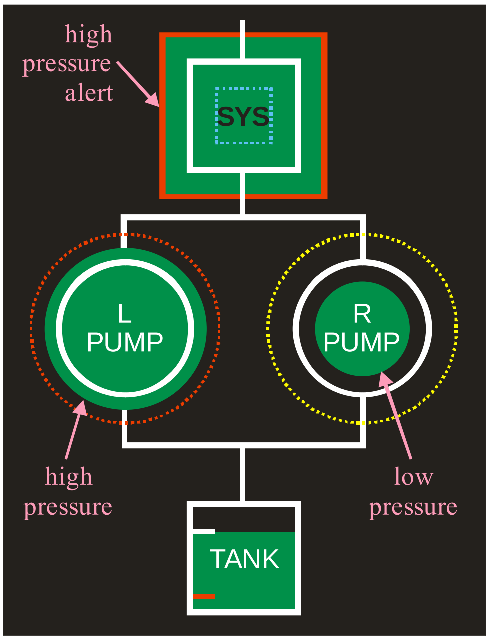

Figure 5. MDO Display with Pressure Changes

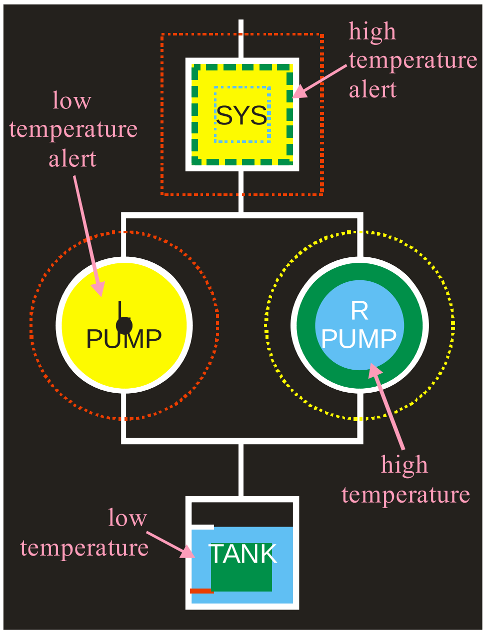

Figure 6. MDO Display with Temperature Changes

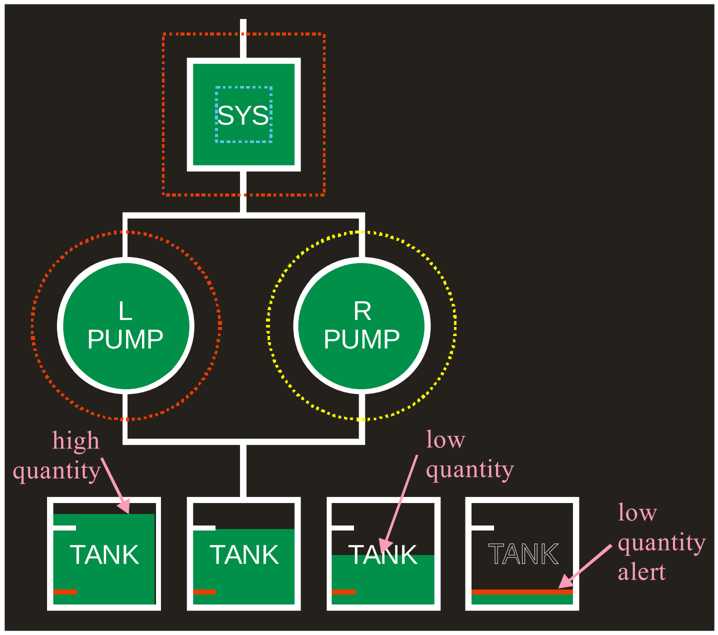

Figure 7. MDO Display with Quantity Changes

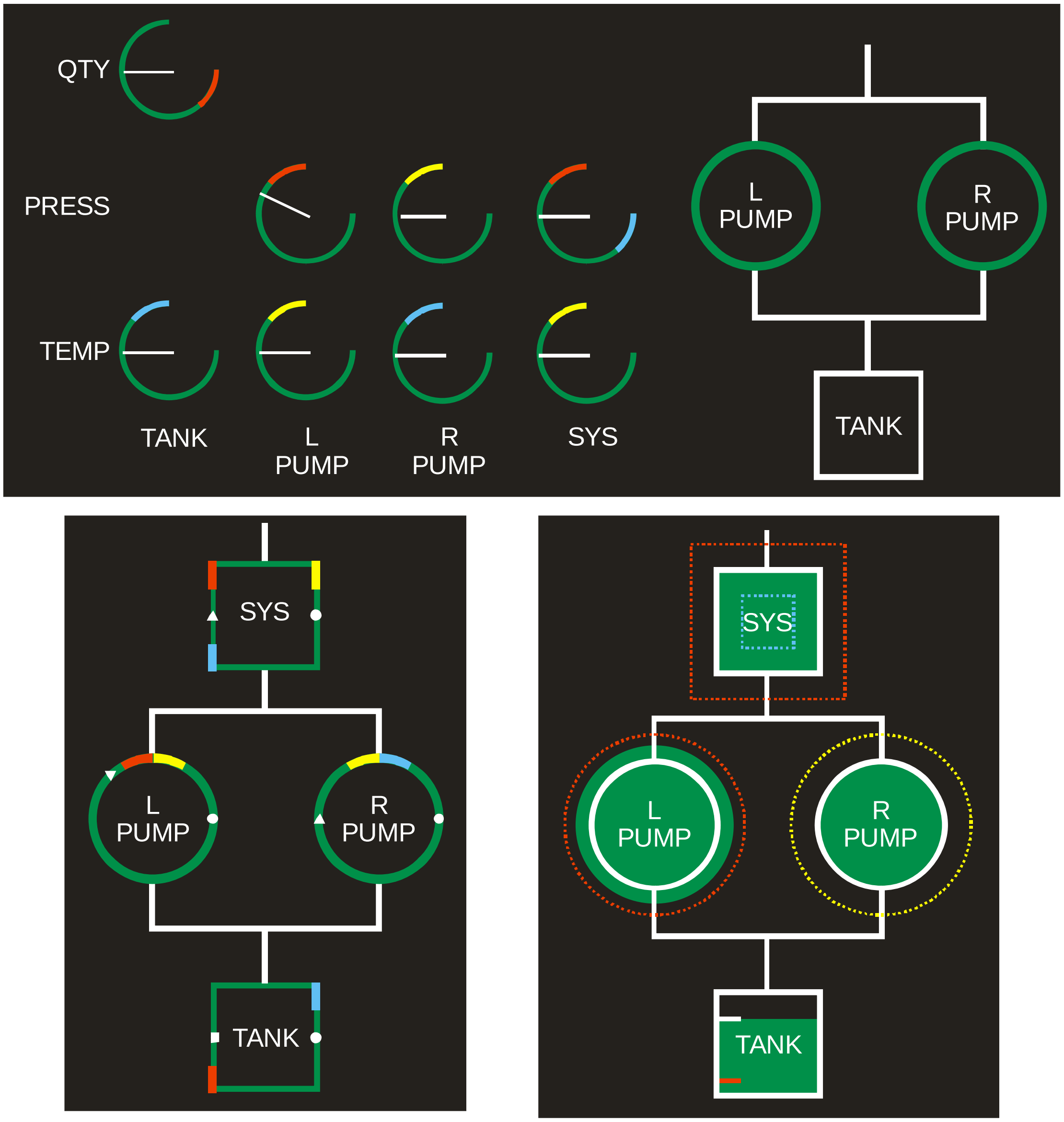

Figure 8. Example Timed Question

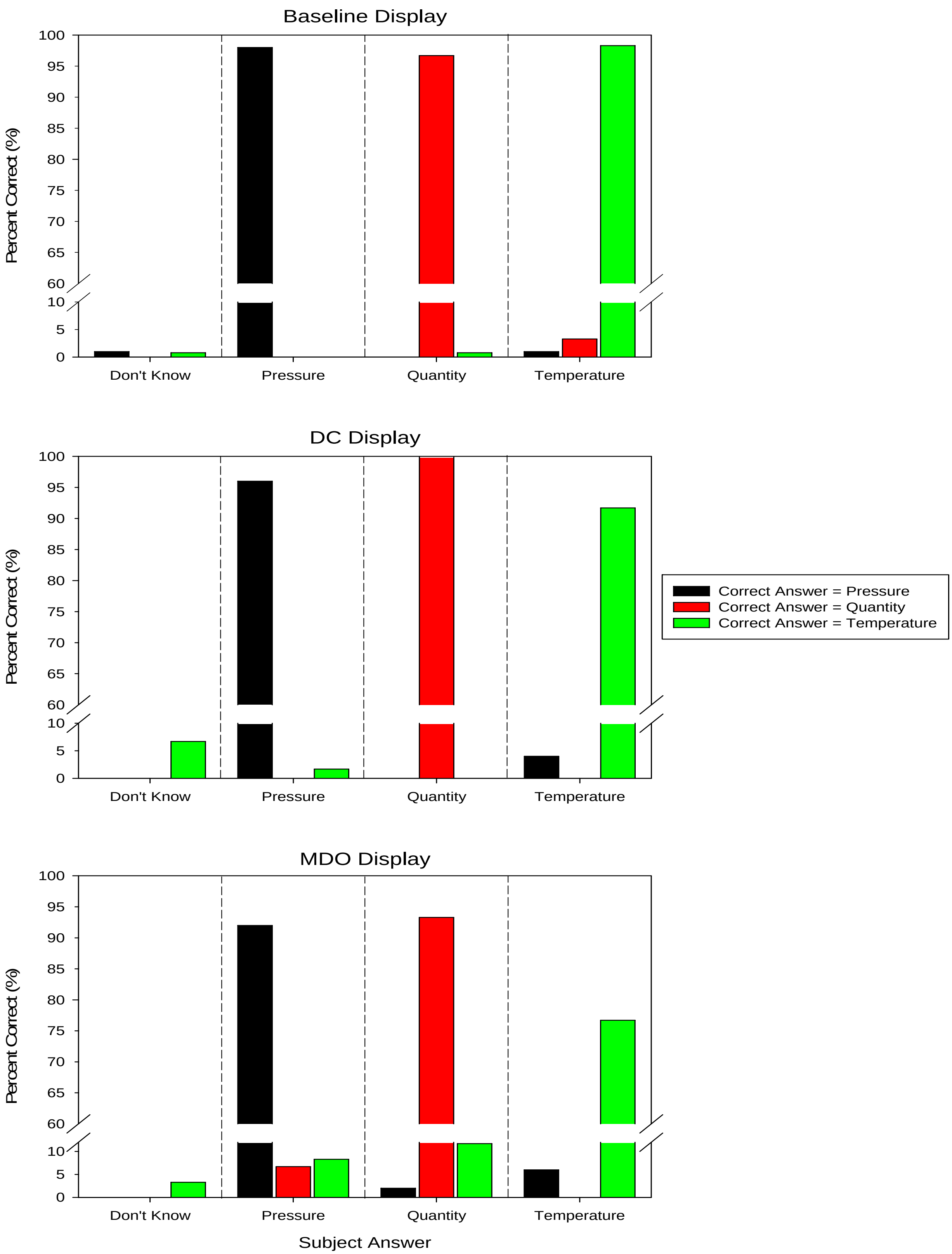

Figure 9. Correctness in Determining Component Parameter Affected

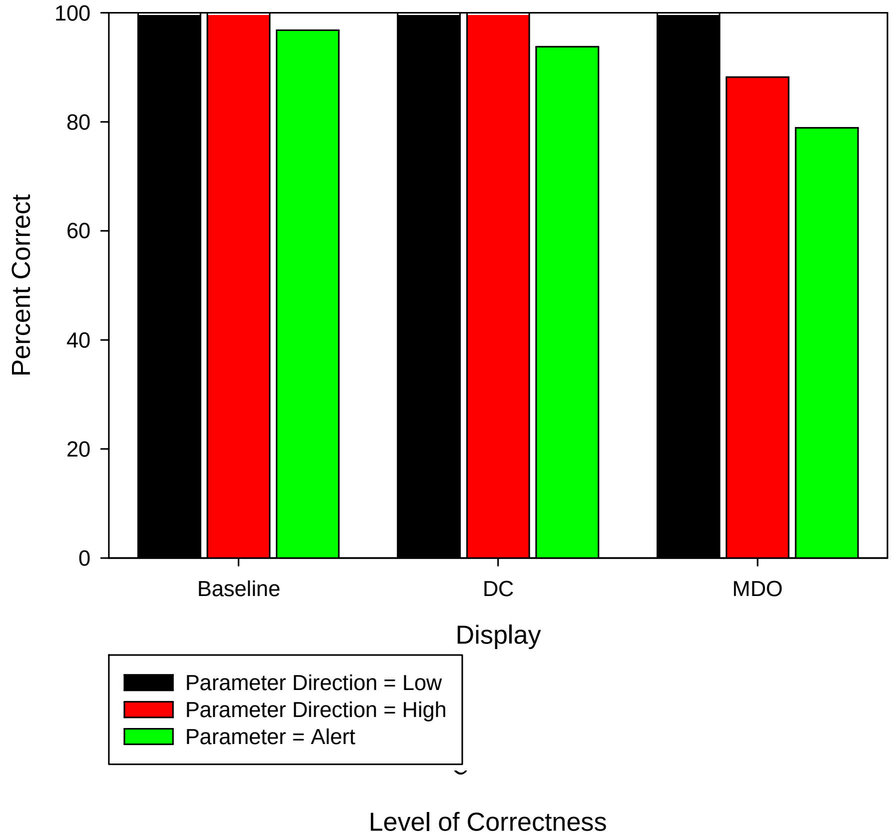

Figure 10. Overall Level of Correctness by Display Type

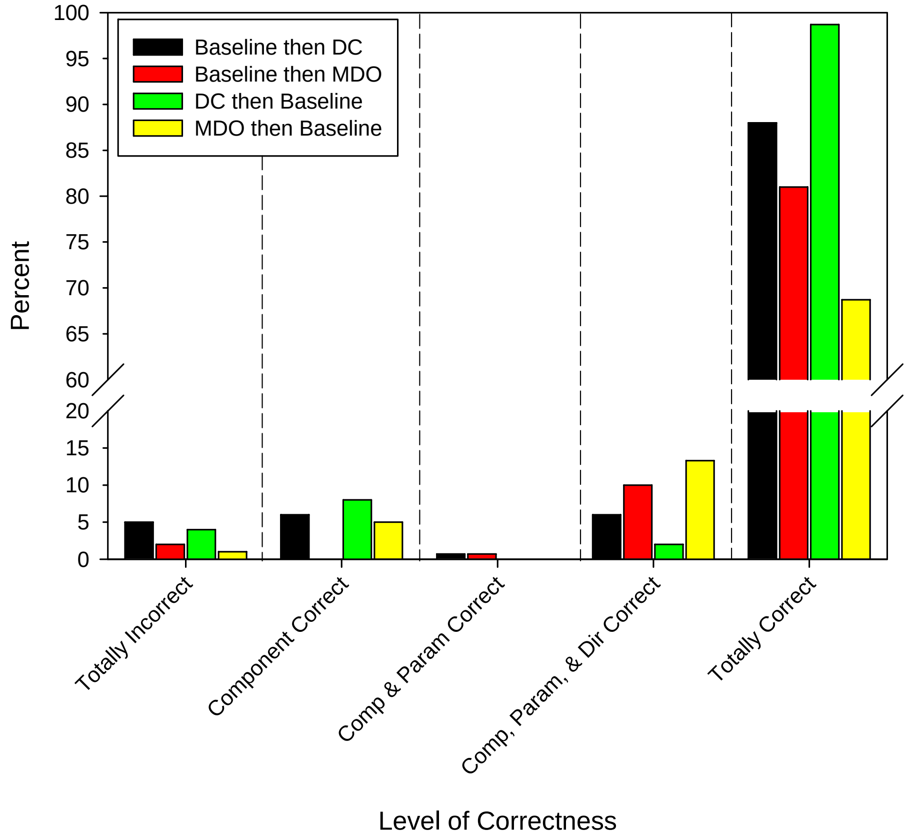

Figure 11. Overall Level of Correctness by Presentation Order

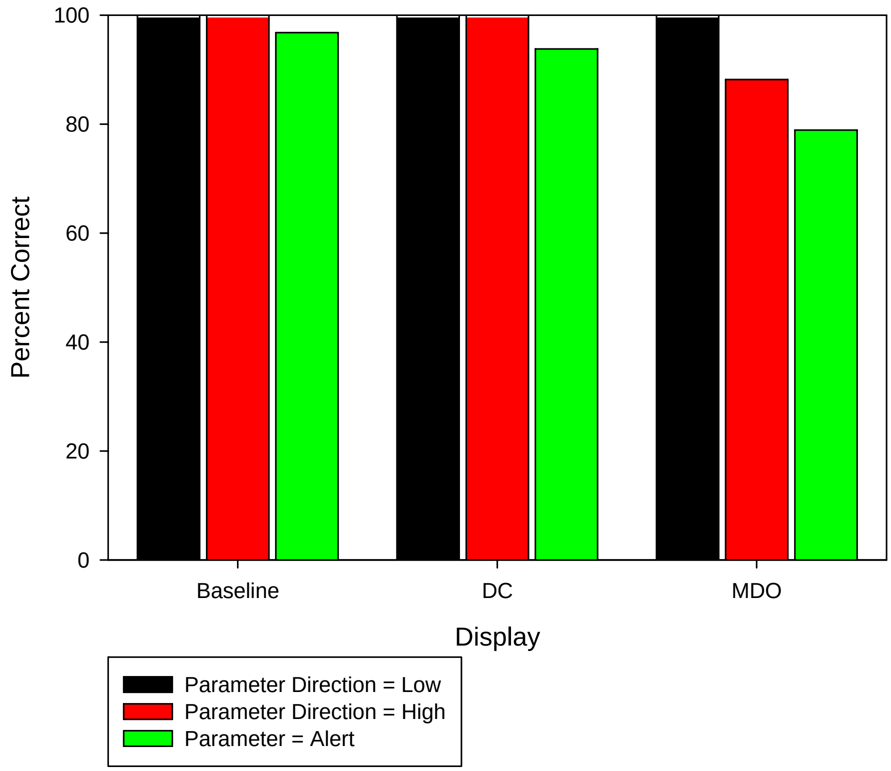

Figure 12. Percent Correct for Determing Parameter Direction by Display Type

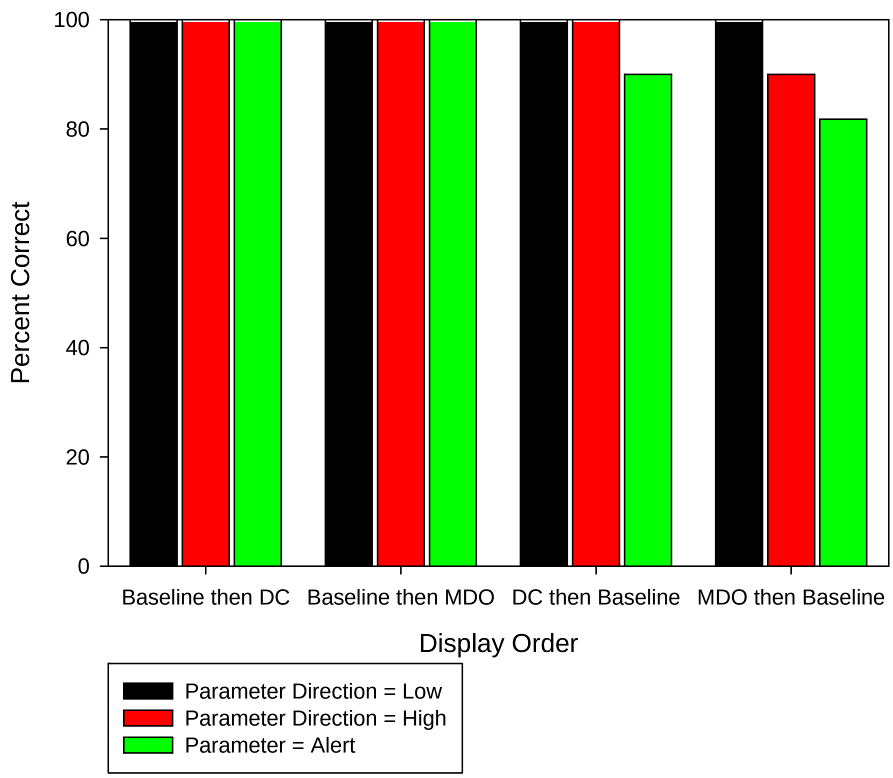

Figure 13. Percent Correct for Determing Parameter Direction by Display Order

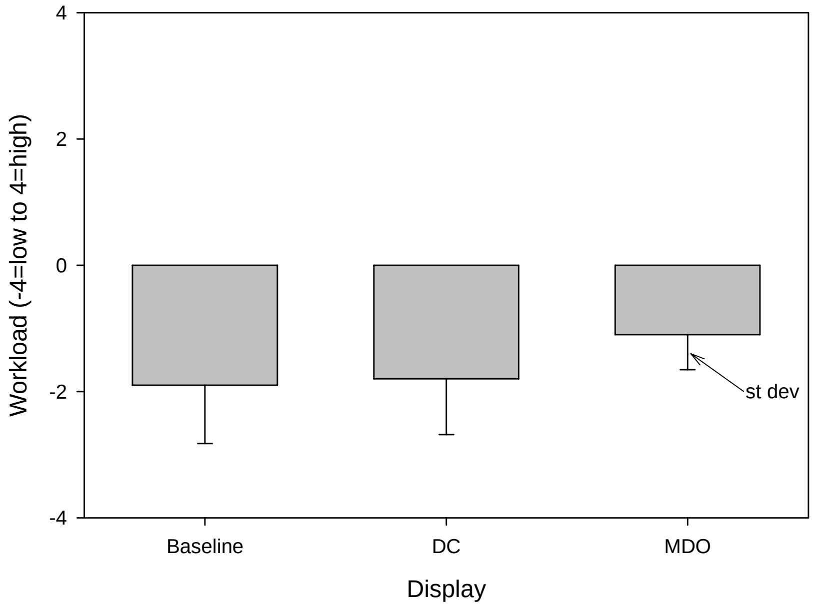

Figure 14. Workload by Display

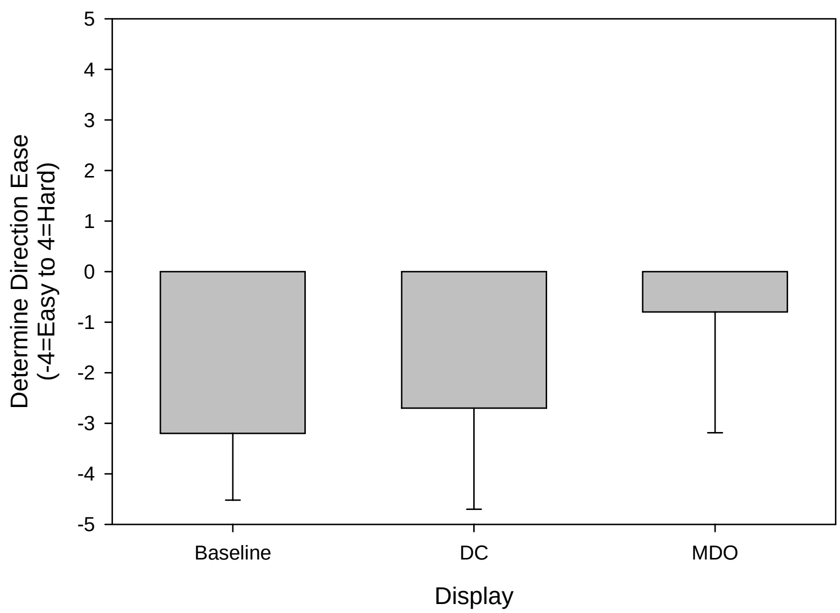

Figure 15. Ease of Determining Direction by Display

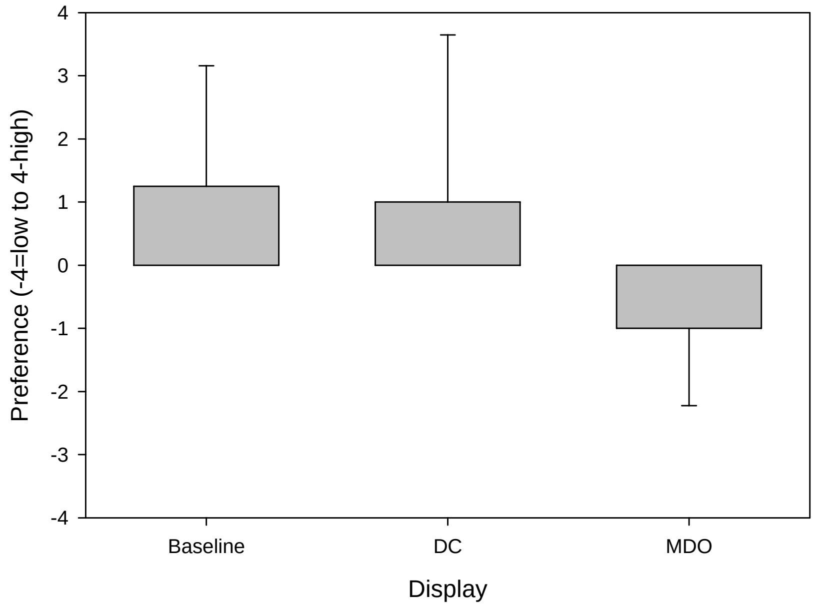

Figure 16. Dial Preference

Appendix A

Human Participants Informed Consent Statement

Title of Research: 4DOF and Dial-on-Control Usability Study

Principal Investigator: Anna C. Trujillo, Research & Technology Directorate, Crew Systems & Operations Branch, (757) 864-8047

Informed Consent:
Federal regulations require us to obtain signed consent for participation in research involving human participants. The purposes of this form are to give you information that may affect your decision whether to say YES or NO to participation in this research, and to record the consent of those who say YES. After reading the statement in IV below, if you wish to consent, please indicate so by signing this form.

Statement of Procedure:
Thank you for your interest in this research. By this time you should have been able to review the description and procedures of this study provided to you by mail or when you arrived. You will find a summary of the major aspects below, including the risks and benefits of participating. Please feel free to ask any questions about the procedures at any time. Carefully read the information provided below. IF YOU WISH TO PARTCIPATE in this study, then sign your name and date the form in the space provided. Also initial all pages at the bottom. Any information you provide will be kept in strict confidence to protect your privacy.

I. I understand that:

1. This is a research study.
2. I will participating in a study to evaluate new display concepts for future flight decks.
3. The study will be performed on a computer workstation. The task will involve answering questions by using a mouse after looking at a picture for 3 seconds.
4. I will receive training on the tasks. I will be allowed time to familiarize myself with the web interface.
5. My participation in this research will involve 1 session of approximately 1 hour.

II. Potential Risks

1. I may experience fatigue using the mouse.
2. No other risks have been identified for this study.
3. In the unlikely event that you are injured or otherwise experience discomfort, the NASA Langley Research Center has a medical clinic available to you and emergency medical personnel and ambulance service is available to transport you to the nearest hospital. If you have questions about the research and your rights should you experience any injury, you may contact the principal investigators listed at the beginning of this document.

III. Potential Benefits

1. I will derive no direct benefit from my participation in this study other than experience with a new avionics display that may be part of aviation platforms that I might fly in the future.
2. The results of my participation may help lead to improved safety, efficiency, capacity, and expandability of the National Aerospace System.

IV. Confidentiality

1. Any information you provide will be kept in strict confidence to protect your privacy.
2. No personal data that you provide will be released in any form.
3. Result data will be keyed only to a test subject number. Only the Principal Investigator will have knowledge of test subject identities.

V. Compensation

1. There is no compensation for participating in this study.
2. Civil servant volunteers participating in the research do so in their official capacity.

3. A civil servant injured as a result of participating in the research may apply for compensation through the Federal Workers Compensation System.
4. Non-civil servant volunteers injured as a result of participating in this research may file a claim under the Federal Tort Claims Act (FTCA) by filing a Standard Form 95. For additional information, you may contact the LaRC Office of Chief Counsel at 864-3221.
4. For additional information, you may contact the LaRC Office of Human Resources at 864-3194.

VI. Freedom to Withdraw

All participation in this study is voluntary. You are free to withdraw from this study at any time without penalty or loss of benefits otherwise available to you. Furthermore, you are free not to answer any questions or respond to any experimental situations that you choose without penalty.

It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study – at any time. Your decision will not affect your relationship with NASA Langley Research Center. Also, the Principal Investigator reserves the right to withdraw your participation in this study, at any time, if she observes potential problems with your continued participation.

VII. Safety

As a voluntary test subject participating in this research, I understand that:

1. NASA is committed to ensuring my safety, health, and welfare plus the safety and health of all others involved with the research.
2. I should report any accident, injury, illness, and changes in my health condition, hazards, safety concerns, or health concerns to Anna C. Trujillo, (757) 864-8047. If I am unable to reach the above named individual(s) or am not satisfied with their response, I should contact the Langley Research Center Safety Office at (757) 864-7233 or the Chairperson of the Langley Research Center Institutional Review Board, Jeffrey S. Hill, (757) 864-5107.
3. If I detect any unsafe condition that presents an imminent danger to myself, or others, I have the right and authority to stop the activity or test. In such cases the Principal Investigator and associated research personnel will comply with my direction, stop the activity, and take action to address the imminent danger.

VIII. Statement of Consent:

I certify that I have read and fully understand the explanation of procedures, benefits, and risks associated with the research herein, and I agree to participate in the research described herein. My consent to participate is given voluntarily and without coercion or undue influence. I understand that I may discontinue participation at any time. I have been provided a copy of this consent statement. If I have any questions or modifications to this consent statement, they are written below:

__________________________ Participant's Name	__________________________ Participant's Signature
__________________________	__________________________ Witness Signature
__________________________ Participant's Address	__________________________ Date
__________________________ Participant's Phone	__________________________ Participant's Date of Birth

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14. ABSTRACT
Currently, most of the displays in control rooms can be categorized as status screens, alerts/procedures screens (or paper), or control screens (where the state of a component is changed by the operator). The primary focus of this line of research is to determine which pieces of information (status, alerts/procedures, and control) should be collocated. Two collocated displays were tested for ease of understanding in an automated desktop survey. This usability study was conducted as a prelude to a larger human-in-the-loop experiment in order to verify that the 2 new collocated displays were easy to learn and usable. The results indicate that while the DC display was preferred and yielded better performance than the MDO display, both collocated displays can be easily learned and used.

15. SUBJECT TERMS
Collocation; System displays; Usability study; Workload

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