Menu Design Considerations for Rapid Decision-Making Simulations

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ABSTRACT

Since there exists no standard interface for simulations, simulation systems must be designed for operation by individuals with very limited experience with the specific training system. Therefore, designers have begun to integrate menu systems into the control schemes of simulations. While menus excel in providing an inexperienced user with easy access to system functionality, they must be properly designed in order to achieve maximum benefit to the user. Many menu-driven tasks must be performed simultaneously with other vital tasks; therefore it is important to develop a better understanding of the effects of divided attention on performance in a menu-driven application. Very little research has been directed toward understanding how menu design features interact with a decrease in available attentional resources due to division of attention across two or more simultaneous tasks. The current study examined the effects of adding an auditory discrimination secondary task to the primary task of interacting with a menu-driven interface. Differences were observed in the patterns of performance and subjective workload under task load among these interface designs. Contrary to previous research, the color coded menu design was not found to improve robustness to secondary task load, and yielded significantly higher subjective workload in the higher task load condition. Performance on the low density menu design was found to be particularly vulnerable to secondary task load, and this finding was reflected in higher subjective ratings of workload in the high task load condition. The grouped menu design, however, yielded no significant degradation in performance in the high task load condition, although significantly higher workload was observed under higher task load. These findings will be discussed in the context of attentional resource allocation, and design recommendations will be made with regard to menu systems intended for use in simulations.

ABOUT THE AUTHORS

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INTRODUCTION

While suspension of disbelief is considered a vital factor in immersive simulations, there is a valid need for low-cost, low-overhead simulations that can interface distance learning applications and assess student performance against a smaller number of learning objectives than larger, more immersive simulations typically support. A common theme of these smaller simulations is ease of use. Since trainees will not spend much time using them, the learning time to properly utilize the simulation should likewise be short. One obvious solution would be a common interface to a family of simulations; once a student has mastered the interface, he/she can apply that ability to all subsequent simulations. For a variety of reasons (e.g., each military service has a number of organizations developing training simulations), this is not a feasible solution. Allowing students to control simulations via graphical menus is a more feasible solution, especially for simulations that require split-second decision-making. Rapid decision-making simulations for training typically involve the addition of multiple tasks. An example would be a simulator designed for training Army infantry leaders to perform typical squad-level leader decisions. At the Infantry Officer Basic Course (IOBC) at Ft. Benning, GA, a live-fire exercise conducted on Ware Range requires newly-commissioned Second Lieutenants playing the role of a squad leader to perform the following tasks simultaneously:

- Observe fire team members moving to contact an enemy position;
- Remembering where a second fire team has placed a base of fire (live ordnance);
- Analyze terrain to determine the best route to cover and conceal the fire team's movement;
- Determine whether to halt fire team members before they enter the base of fire zone and execute the proper command;
- Correctly remember to signal "shift fire" to the second fire team;
- Correctly remember which signaling device was designated earlier as the "shift fire" device;
- At the proper time, issue the "shift fire" signal (typically a smoke grenade);
- Correctly recall the secondary signal, should the primary signal fail to employ or be noticed by the second fire team;
- Look or listen for the second fire team's response to the "shift fire" signal;
- If the first fire team was halted, advance them only after the second fire team has shifted fire.

During the live fire exercise, this set of ten tasks would ideally take place in the span of 60 seconds or less. While the students have been through the exercise twice previously (a walk-through and a blank-fire have been conducted prior to the live fire), the addition of live ammunition makes the live fire exercise much more intense.

Students participating in the Ware live fire exercise are subjected to an incredible (but realistic) task load, yet their interfaces to hardware devices (in this case, smoke grenades and small arms) are well understood. In a training simulator, however, the interface may not be as familiar to them. As an example, imagine a devotee of a particular first-person shooter PC game (e.g., Quake, Rainbow 6, Delta Force) playing a new game. While certain interfaces are fairly standard (e.g., mouse movement to change orientation, arrow and "WASD" keys to move, and right mouse click to fire), other commands may not be unless the game engine allows the player to map commands to buttons or key clicks. Unfortunately, there is no standard for commands in training simulations.

A key decision factor regarding complexity of student-simulator interface is the amount of time a student will spend using the simulator. A simulator that will engage the student for long periods of time may have a more complex interface than a simulator that a student will not use for long.

A work-around to this dilemma is to allow students to select commands via a menu-driven interface. Such an interface would limit the keyboard/mouse commands a student must learn, while providing a complete set of commands the student can execute. However, developers cannot simply substitute menu-driven commands for keyboard input, joystick controls, or other user interface methods without an understanding of the user interface issues of menu designs. The US Marine Corps' Training and Education Command states "non-intuitive menus…contribute to a good simulation never being used." (TECOM, 2001)

BACKGROUND

The Rapid Decision Trainer (RDT), developed by the US Army's Research, Development and Engineering Command Simulation and Training Technology Center (RDECOM STTC), is a prime example of a low-cost, low-overhead simulator that is not intended to engage a student for long periods of time. Developed for IOBC, the RDT is intended to augment squad-level and platoon-level live fire exercises at Ft. Benning's Ware and Griswold ranges, respectively. Students must go through these live fire exercises, but due to constraints (time, money, and environmental), only about 10% of each IOBC class can complete the exercise in a leadership role. IOBC requested assistance from STTC in developing a game engine-based simulation that was engaging, doctrinally correct, and replicated the live fire exercises.

Early in the design process, STTC and Subject Matter Experts from IOBC decided that, due to the limited time students would spend using RDT, the interface would need to be as simple as possible. Commands typical of an infantry squad performing battle drills training were presented via a menu system. Unfortunately, even with a unit as small as a squad, there are two sub-units (fire teams), each with their own commands. The original menu had 47 commands with no color-coding or grouping applied. Parallel to the development of the RDT, a University of Central Florida (UCF) class group took the menu design of the RDT as a class project, seeking a more optimal menu design for the squad-level trainer. This project led to a follow-up project by the same team the following semester. These projects led to important design considerations for both the squad-level and, ultimately, the platoon-level implementations of the RDT.

FEATURES OF MENU DESIGN

A great deal of work has been performed on various aspects of menu design including color coding (Christ, 1975; Tullis, 1981; Yeh & Wickens, 2001), presentation format (Grace, 1966;_Vincino & Ringel, 1966), grouping (Kahneman & Henick, 1977, Mayzner and Gabriel, 1963, and Winzenz, 1972), and display density (Brown & Monk, 1975; Ringel & Hammer, 1964; Triesman, 1982). Unfortunately, very little work has addressed the issue of how these various features of menu design are affected by a decrease in available attentional resources due to division of attention across two or more simultaneous tasks. Many menu-driven tasks must be performed simultaneously with other vital tasks; for instance, a disaster response coordinator may have to navigate a menu while talking on the phone, or giving directions over the radio to rescue teams. Similarly, an infantry commander in the field may need to interface with a computer-based menu-driven command and control aid while simultaneously issuing orders to or receiving information from other units. Therefore, it is important to develop a good understanding of the effects of divided attention on performance in a menu-driven application. To that end, the current study examined the effects on attention of adding a secondary task to the primary task of interacting with a complicated menu-driven interface.

The optimal test case would have used actual IOBC students; however, the course schedule does not allow a lot of extra time, and the UCF class project team decided to use UCF students. These students would not be familiar with Army tactics, thus, an "artificial" secondary task load, an audible signal, was utilized to simulate a stimulus that would cause an IOBC student to issue a command (i.e., select a choice from a menu.)

METHOD

Participants

Fourteen participants (4 men and 10 women, mean age = 22.5 years) were recruited on a voluntary basis from undergraduate psychology classes at UCF. Participants were screened for computer and video game experience.

Materials

Questionnaires

Participants were asked to complete several questionnaires over the course of the study. Participants began by reading and signing two copies of an informed consent form, one of which the participant kept and one signed copy of which was retained by the researchers for record-keeping purposes. Participants then completed a demographic questionnaire presented via computer. Following each block of trials, participants were asked to complete a computer presented version of the rating scales section of the NASA-Task Load Index (TLX), a subjective workload assessment (Hart & Staveland, 1988). The NASA-TLX is a well-known measure of workload using six independent rating scales to derive measures of frustration, performance, temporal demand, physical demand, effort, and mental demand (Hart & Staveland, 1998). This measure has been identified by a recent review as one of the most sensitive measures of workload available to researchers (Hill, Iavecchia, Byers, Bittner, Zaklat, & Christ, 1992). For this study, only the first part of the index, the rating scales section, was used because it represents a simpler alternative to the NASA-TLX. A number of studies have found the means and standard deviations of this version of the NASA-TLX, known as the Raw Task Load Index (RTLX), to be very comparable to the full NASA-TLX (Byers, Bittner, & Hill, 1989; Fairclough, 1991), with a Pearson's product-moment correlation above $r = 0.95$.

Upon completion of the study, participants were debriefed verbally and received a written copy of the debriefing statement. This form contained contact information in the event that the participant needed to contact the experimenters at a later date.

Computer Programs

Both the primary and secondary tasks were administered on two personal computer workstations using Inquisit, a commercially-available experimental presentation program (Millisecond Software, 2002). One computer presented a menu-driven primary task while a second computer simultaneously presented an auditory secondary task.

Tasks

Primary Task

The primary task consisted of a mouse operated menu interface in which participants were required to select a series of menu options. Each block consisted of 30 trials in which the participant was asked to select one option from the menu screen. Each of the blocks utilized a single menu type (control, low-density, grouped, and color-coded). The control menu contained 30 items and utilized no special method of organization and was presented in monochrome. The low density menu type showed only half as many menu items as the control menu design, and the items were evenly distributed around the available screen space. The color coded menu design used a color-coding scheme to identify items based on their relationship with one another, and the grouped menu design spatially grouped items based on their relationship and delineated the boundaries of these groups with a solid white box.

All menu items were labeled with phrases characteristic of orders common to the tasks and requirements of infantry combat officers. Participants were individuals without previous military experience in an infantry combat domain.

Secondary Task

The secondary task consisted of a series of tones, a low-pitched tone (500 mHz) and a high-pitched tone (1000 mHz). Tones were separated by approximately 3 seconds. The participant was provided with a keypad and was required to push one button every time the low tone was heard and another button every time the high tone was heard.

Design

4 (menu design) x 2(secondary task) factorial design was used. The 4 levels of menu design consisted of a color-coded menu design, a low density menu design, a grouped menu design, and a control design. The two levels of secondary task manipulation consisted of a condition in which the secondary task was present and one in which the secondary task was absent.

Procedure

Testing occurred over a single one hour session. In each session, participants completed eight blocks of ten trials. All trials consisted of one presentation of one of the menu interfaces, preceded by an instruction screen that identified the menu options participants were to select on the interface. At the conclusion of each block of trials, participants completed the rating scales section of the NASA-TLX. Each block contained trials using one of the four interface designs: control, color coded, grouped, and low density. Four of the eight blocks were completed under low task load conditions without the secondary task present. The other four blocks were completed simultaneously with the secondary task. The sequence of presentation for all blocks was counterbalanced to control for order effects. Menu selection response time was recorded during each block of the experimental phase. Prior to completing the experimental phase, participants received 2 practice blocks with the secondary task and 2 without. In addition, the participants received a practice session of the NASA-TLX.

Results

An overall repeated measures analysis of variance (ANOVA), 4 (menu design) x 2 (task load) was performed in order to test our hypotheses regarding the effects of menu design and secondary task load on response time. A main effect of menu design was observed, $F(1,11) = 14.35$, $p = .0004$, $\eta^2 = .800$, confirming that there were significant differences in response time as a function of menu design. Additionally, a main effect of task load was also observed, $F(1,13) = 8.13$, $p = .014$, $\eta^2 = .39$. Consistent with our hypothesis, it was found that response time increased in the presence of the secondary task ($M = 2170.73$, $SE = 151.26$) versus when no secondary task was present ($M = 1918.34$, $SE = 98.97$), when collapsing across all menu designs. No significant interactions were observed. However, since we had specific hypotheses regarding certain interactions between menu designs and task load, preplanned comparisons were performed using paired-samples t-tests. All means and standard deviations are reported in table 1 below.

In order to test the hypothesis that reaction time using the color-coded menu design would not increase in the presence of a secondary task load, a preplanned one-tailed paired sample t-test was performed. Consistent with this hypothesis, no significant effect was observed.

In order to test the hypothesis that response time using the color coded menu design would be better than that observed when using the control menu design a preplanned one-tailed paired samples t-test was performed. Contrary to this hypothesis, response time using the color coded menu was greater, $t(14) = 663$, $p = .025$.

In order to test the hypothesis that reaction time using the grouped menu design would increase in the presence of a secondary task load, a preplanned one-tailed paired sample t-test was performed. Consistent with this hypothesis, reaction time was significantly higher in the presence of the secondary task, $t(14) = .914$, $p < .002$.

In order to test the hypothesis that response time using the grouped menu design would be better than that observed when using the control menu design a preplanned one-tailed paired samples t-test was performed. Contrary to this hypothesis, response time using the grouped menu was greater, $t(14) = .685$, $p = .0035$.

In order to test the hypothesis that reaction time using the low-density menu design would increase in the presence of a secondary task load, a preplanned one-tailed paired sample t-test was performed. Consistent with this hypothesis, reaction time was significantly higher in the presence of the secondary task, $t(14) = .788$, $p < .0005$.

In order to test the hypothesis that response time using the low-density menu design would be better than that observed when using the control menu design, a preplanned one-tailed paired samples t-test was performed. Consistent with this hypothesis, the reaction time was greater on the control menu design than the low density menu, $t(14) = .803$, $p = .0005$.

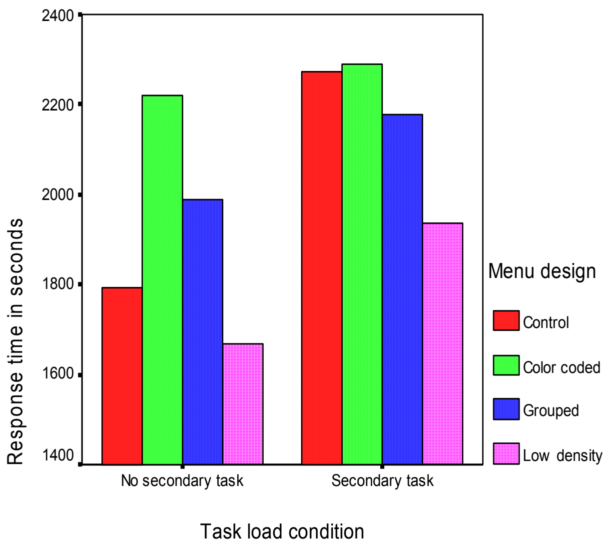

Figure 1. Response time as a function of menu design and task load condition.

DISCUSSION

This study identified a number of findings with significant implications for designing menu interfaces when the user is expected to encounter additional task load while operating. Because this study examined grouping, density, and color-coding manipulations of menu design, it provides a basis for comparing these design elements both to a traditional menu design and to one another. With regards to color, the present study extended the findings of Remington, Johnston, Ruthruff, Gold, and Romera (2000), and Yeh & Wickens (2001) to a condition in which a considerable secondary task load was present. Additionally, this study supported the contention of Triesman (1988) and Triesman and Gelade (1980) that processing of color coding schemes is effortless. However, the current finding that participant's response time was greater when using the color coded menu design than when using the control menu suggests that color may not in fact be as beneficial as many researchers in the field believe it to be. Moreover, these results provide evidence against the use of color-coding schemes in menu design when rapid reaction time is an important element of performance and task load is not expected to be critical. In essence, these findings suggest that the use of color coding schemes present a tradeoff; such menu designs appear to cause the performance of users more robust to the effects of task load, but at the cost of increased response time overall, regardless of the workload the user experiences.

The present study also examined the effects of display density on performance. Decreasing the density of the display improved response time dramatically, but the significant effect of the secondary task on response time on this menu suggests that this design element is vulnerable to increases in task load. Significantly, this increase in response time would actually appear to make the low-density display less effective than the control menu under high task load conditions. This is consistent with the findings of Triesman (1982), which found that performance using a low density display can also be degraded if display elements are separated by too much empty space, and Fitts (1947), which also argued that performance can be degraded by separating stimuli spatially.

Table 1. Paired Samples Descriptive Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Control menu, no secondary	1794.6429	14	494.60292	132.18819
	Control menu, secondary present	2274.6548	14	539.29751	144.13332
Pair 2	Color-coded menu, no secondary	2221.8905	14	659.26484	176.19594
	Color-coded menu, secondary present	2290.8762	14	1013.0246 6	270.74223
Pair 3	Grouped menu, no secondary	1989.6119	14	472.53597	126.29055
	Grouped menu, secondary present	2179.6738	14	600.59124	160.51476
Pair 4	Low-density menu, no secondary	1667.2190	14	472.70479	126.33567
	Low-density menu, secondary present	1937.7286	14	552.84871	147.75503
Pair 5	Reaction time with secondary task present, collapsed across menu designs	2170.7333	14	565.96190	151.25968

	Reaction time with no secondary task present, collapsed across menu designs	1918.3411	14	370.32790	98.97429
Pair 6	Control menu collapsed across task load	2034.6488	14	441.57496	118.01587
	Color menu collapsed across task load	2256.3833	14	586.31678	156.69975
Pair 7	Control menu collapsed across task load	2034.6488	14	441.57496	118.01587
	Grouping menu collapsed across task load	2084.6429	14	525.01783	140.31692
Pair 8	Control menu collapsed across task load	2034.6488	14	441.57496	118.01587
	Density menu collapsed across task load	1802.4738	14	484.98104	129.61664

Finally, this study found similar effects of display element grouping on performance under task load to those observed in the control and density menu designs. This pattern of results indicates effortful processing and suggests that these menu designs are all vulnerable to some extent to increases in task load.

A number of design recommendations can be made based on the findings of the present study. Firstly, that there are important differences in the pattern of user response to task load across menus incorporating different design elements. More specifically, it is recommended that low density and grouped displays, while helpful under low task load conditions, should not be used in systems where high task load on an operator is likely. However, it appears that displays incorporating color coding are not effective at improving performance under low task load conditions, but that the response time of users operating these displays shows almost no degradation under conditions of high task load. This finding has implications for the design of future menu systems which may need to be used under high task load conditions. In essence, designers contemplating the incorporation of color coding into menu interfaces must carefully weigh the evident costs to overall response time against the apparent immunity to increased task load that such interfaces appear to confer.

The present study has identified significant and interesting results which make clear and useful predictions about performance using a number of menu designs under high task load conditions. It is hoped these findings will be used to assist in the design of future menu interface systems so as to maximize the performance of menu users, particularly under conditions in which they experience high task load.

Implications for the Rapid Decision Trainer

As discussed earlier, the inspiration for this study was the Rapid Decision Trainer being developed for the Infantry Officer Basis Course. The original menu system was not designed using any of the findings from the existing literature. However, developers were presented with results of a pilot study. It was decided that the most inexpensive modification to the menu system was a simple grouping, coupled with an internal decision to allow for different menus screens for different echelons of commands (e.g., squad, Alpha team, Bravo team.) As the Rapid Decision Trainer undergoes more development to produce a multi-player, platoon-level trainer, more emphasis on applying lessons learned in the study will be important. This is particularly important in the context of secondary task load. While the study instituted a secondary task more as a way to compare results with previous findings, the findings are important to Rapid Decision Trainer as infantry leaders are faced with a variety of decisions that must be made in a timely basis.

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