

The Effect of Overview Displays on Situation Assessment

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ABSTRACT

The impact of overview displays when operating in a simulated environment (SimCity 2000) was assessed. Subjects in one condition had access to a fixed overview display on a separate CRT (an additional display that was absent in the no overview display condition). The experimenter operated the simulation based on the verbal instructions of the subjects. More trends were detected, and more verbalizations, in the overview display condition. There was also more discussion of the simulation state and more transitions from commenting about states to preparing actions, with the overview display. It is argued that the methodology used in this study, and the results obtained, demonstrate that measures such as situation assessment may be easier to interpret than performance measures, and less variable, because they are less likely to be influenced by extraneous factors. Thus they may be more sensitive indicators of the effect of changes in display design.

1. INTRODUCTION

Utilities are building the next generation of control room interfaces using increasing amounts of computer technology. Large central overview displays are major features of the new control rooms. Their large size and location make them visible to all control room operators. However, we need to understand how useful such aids are in supporting operators as they perform their tasks.

One approach to this type of problem is to adopt a usability engineering approach (e.g., Nielsen and Mack, 1994; Nielsen, 1997) where scenarios are constructed with the new technology, and usability problems are identified. Usability engineering generally works best within an iterative design framework that seeks to improve a design, rather than test its basic assumptions.

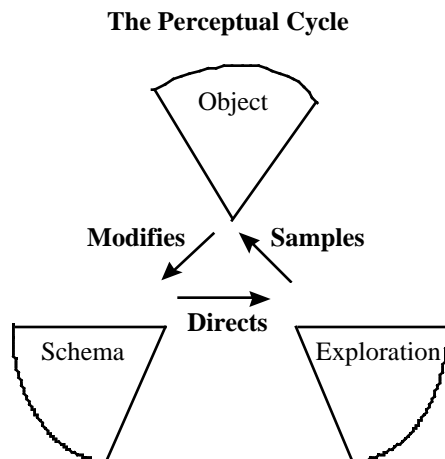


Figure 1. The Perceptual Cycle (Figure 2 in Neisser, 1976).

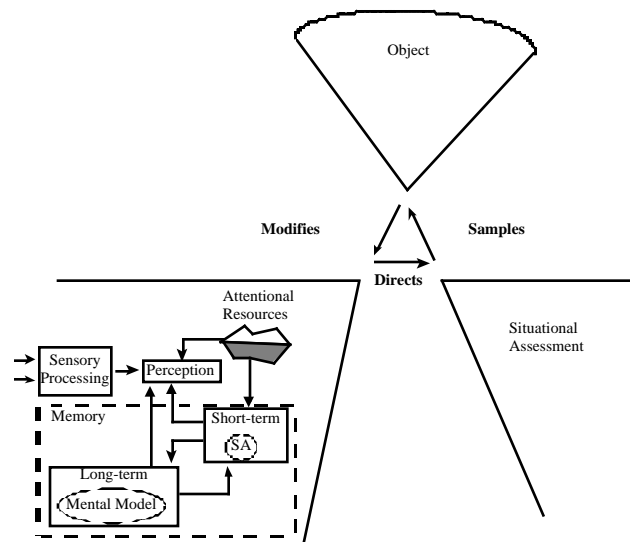


Figure 2. The Modified Perceptual Cycle (after Rivera, 1996, Figure 5).

This study addressed the question of whether overview displays can be effective, and if so, how they should be constructed. This paper will present early results on whether or not overview displays improve the subjects situational awareness (SA) and situational assessment (SAss). It is argued that these measures are likely to be more sensitive to the effects of overview displays than are performance measures.

This research was motivated by Neisser's characterization of the perceptual cycle (as shown in Figure 1, after Figure 2 in Neisser, 1976). In Neisser's view, schema (roughly interpretable as models of the world) direct exploration of the perceptual environment, which in turn, leads to sampling of objects in that environment, thereby modifying the world model. The updated world model is

then used for further exploration, thus starting a new round of the perceptual cycle. Neisser's illustration of the perceptual cycle can then be modified to include a consideration of cognitive processing, situation awareness, and situation assessment, as explained in the following paragraph.

In an applied process control setting the perceptual action cycle illustrates the need to provide operators with displays (environment) that aid them in gathering information on plant state. In addition, the cycle illustrates the role of the operators' cognitive structure (i.e., mental model). The information processing view of cognition (e.g., Wickens, 1992) can then be incorporated into the perceptual cycle (as shown in Figure 2). For an alternative modified view of the perceptual cycle (which also influenced our approach, see Adams et al., 1995). Another issue that can be incorporated within the framework of the perceptual cycle is situational awareness (SA), as explained by Rivera and Chignell (1995). In this view SA is part of the mental model that the operator forms (the schema, in Neisser's terminology), while situation assessment is part of the exploration phase of the perceptual cycle (Rivera and Chignell, 1995). Endsley (1988, 1994) has described situational awareness as a complex process of perception and pattern matching greatly limited by working memory and attention capacity. This process is described by Endsley as consisting of three levels.

Level1: Perception of the situational elements.

Level2: Information Integration: Based on schemata, or knowledge structures stored in long-term memory. Which are activated by recognized patterns in incoming data, pilots form a coherent view of the current situation in working memory. Which then determines their further information search and attention allocation.

Level 3: Projection of future status and actions of situational elements. This level is the basis for "being ahead of the plane".

Situation assessment is the process of collecting the information needed to maintain good situation awareness (SA). Roth et al (1994) listed the following behaviors as examples of searches for explanation associated with situation assessment:

- * detecting abnormal plant behavior
- * identifying problems (e.g., plant malfunctions)
- * detecting alarms/symptoms that had been missed

An overview display and associated training should facilitate operators in developing improved awareness of task relevant information and guide them in sampling information. It is hypothesized that SA and Sass are mediating variables between overview display design and resultant performance (see Figure 3). This relationship

follows from the activity of the perceptual cycle shown in Figures 1 and 2. For instance, the act of exploration or assessment is facilitated by a good overview display leading to the right branch of the figure. This branch continues with a resulting improvement in SA due to the higher quality of information obtained through Sass. Each of the boxed elements in Figure 3 can in principle be observed and measured. Thus analysis of the correlations and dependencies between these measures may be useful in assessing causal flow and in determining which measures should be used in evaluating the effect of different display designs and task variables.

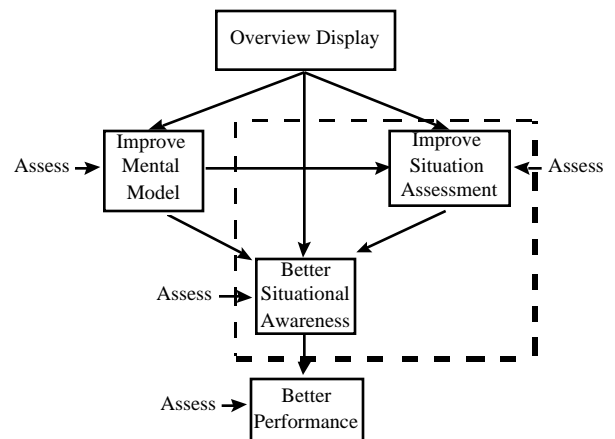


Figure 3. Relationship between overview display, mental model, SA, situation assessment, and performance (after Rivera, 1996, Figure 5).

A good overview display also acts as a conceptual model of the process being operated on, which may also improve the mental model of the operator (as shown in the left branch of Figure 3). This improved mental model may in turn improve Sass, and subsequently SA, or it may improve SA directly by making it easier to assimilate the information obtained through Sass. Since performance may be influenced by many different factors, not all relating to design, assessment of display usability in terms of SA and Sass factors may provide more sensitive and diagnostic information about the effects of different designs. Thus in the experimental study described below, these constructs were utilized.

2. METHOD

The experiment evaluated the effect of an overview display on SA and Sass while using SimCity 2000 (a computer simulation game). SimCity 2000 was selected because it has some of the characteristics of the nuclear power plant environment. For instance, the state of the city is given by a combination of variables such as availability of funds, level of crime, and level of pollution. Pollution, in turn, is a factor of traffic, water and industrial pollution. SimCity 2000 is a popular game that is generally considered to be fun to play. This helps

subjects to become engaged in the game and makes it easy to train subjects who are not familiar with the game.

Overview Display Design

The overview display (Figure 4) presented subjects with goal based information about city state. Information about the functional purpose of the city was shown (cf., the abstraction hierarchy, Rasmussen, 1986). The display was implemented using SuperCard.

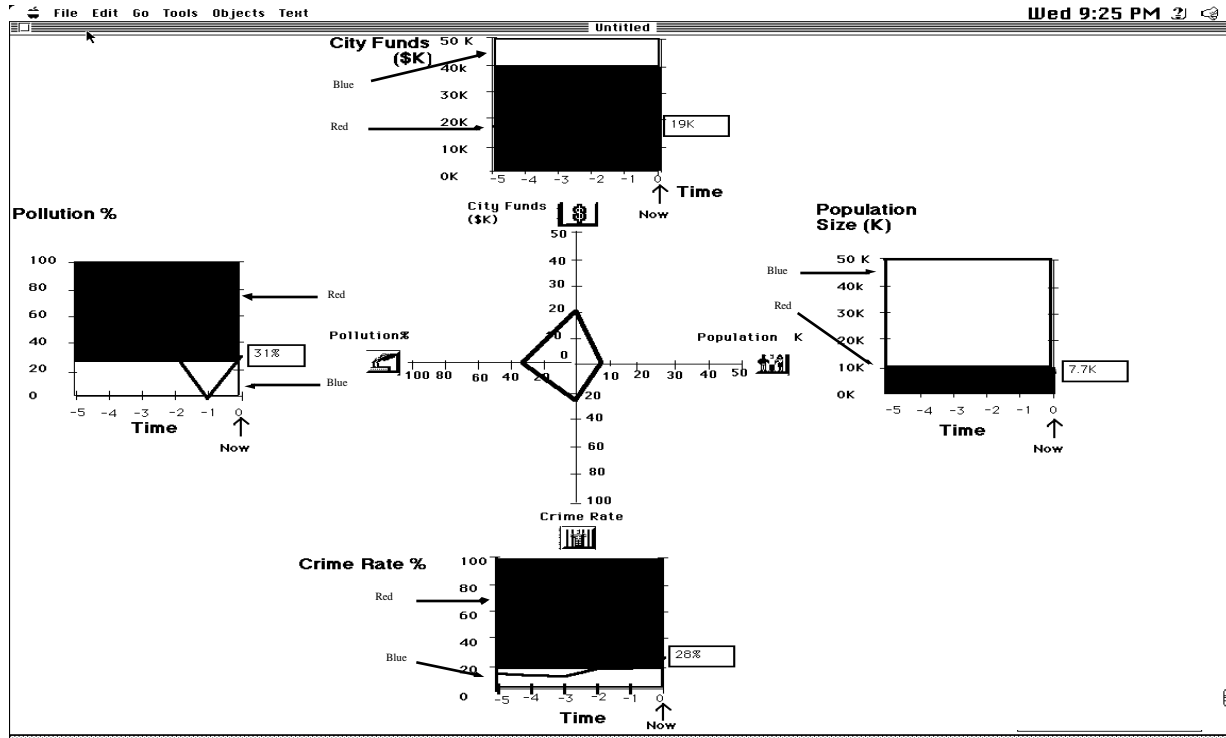


Figure 4. Display used in Experiment.

Experimental Design

The main objective of the study was to determine the effect of having a display on separated and dedicated CRT, on subject SA and situational assessment behavior. The goal of SimCity 2000 is to build a successful city in terms of the four high level variables: energy, population size, city funds, crime rate. At the beginning of each session subjects were given a trial scenario where they were allowed to ask any questions regarding their task. This was followed by the data collection session during which subjects were asked to think aloud. The experimental sessions were videotaped and subject verbalizations were captured.

A two factorial design was used for the study. Display setup was the first factor with two levels: overview display present, or not present (no overview display). The second factor was the "type of scenario". During each scenario the game settings were twice changed (examples of variables being changed included taxes and police funding) by the test administrator. Subjects were not told when and what changes were to be made. Different game settings were changed for each of the scenarios. Subjects were asked to monitor the four high level variables and report any deviations from the goals given. If the variables deviated from their goal then they had to identify

the cause for the deviation and take corrective action. This involved asking questions about any high (crime rate) or low (number of police stations) parameters of SimCity simulation. An example of a high level question was: What is the population size of the city?

Eight volunteer subjects, all university students, took part in the study. Subjects were randomly assigned to the four combinations of display set up and scenario order. Two subjects were used in each cell of the design, with each subject being exposed to two scenarios (one easy and one difficult). Each subject performed both scenarios (easy and difficult) under one display set up only. Difficulty was defined by how demanding it was to identify the problems and solve them, according to the size of the city and the geography of the land. Ordering of the scenarios was counterbalanced so that half of the subjects in each display set up condition (display vs. no display) did the easy scenario first while the remainder did the difficult scenario first.

Measures

To assess SA, four question were asked about the state of the city in terms of the high level goals. These were administrated in the form of questionnaires at the end of each scenario.

MacShapa (Sanderson et al., 1994) was used to analyze the verbal protocols. Each verbalization was transcribed and then classified by the type of situation assessment behavior it represented. The transcription and classification was carried out for all the data in the experiment (i.e., for all the combinations of scenario and display set up).

Each verbalization was classified according to a framework based on the general tasks as proposed by Stubler et al (1991), in conjunction with the observed situation assessment behavior proposed by Roth et al (1994). This produced the verbalization codes shown in Table 1.

Task	Observed Behavior	Verbal Content
Monitoring:	Observation	State
		Problem
Diagnosis:	Search for explanation	General query
		Explanation
Control:	Anticipate future problems	Action
		Strategy

Table 1. Verbalization Classification Framework.

The verbalization codes were further qualified depending on the type of observed behavior they represented. Each code used two to three qualifiers (arguments) to provide more information about the verbal content. For instance, a coded verbalization like state(crime, high, normal) meant that it was about the high level variable crime and that its current level was within acceptable levels.

3. RESULTS

Questionnaires

There was a significantly greater number of trends detected in the overview display condition (Wilcoxon signed ranks test, $z=-2.05$, $p<.05$) versus the no overview display condition. There were no significant differences in knowledge about overall city state (normal/abnormal) or about the goals of the city question (as assessed by the two questions used to address these issues in the questionnaire). However, subjects were more knowledgeable about both city funds ($z=-2.38$, $p<.05$), and crime ($z=-2.39$, $p<.05$) in the overview display condition.

Using MacShapa, the transition matrices were generated and a t-test analysis was carried out. The first analysis was done on the total number of verbalizations between the No Overview Display and Display present conditions. The analysis was based on the seven verbalization categories (state, general query, action, problem, explanation, anticipation, and strategy) as observations, with the value of each observation being the total number of verbalizations that occurred for the corresponding category. There was a significant difference for total number of verbalizations, with more verbalizations

occurring in the overview display condition ($z=-3.46$, $p<.01$).

Separate analyses were then carried out (one analysis for each of the seven categories) to find out if each observed difference was statistically significant. Only the difference observed for the State category was statistically significant ($p<.05$). Verbalizations concerning the state of the simulation increased significantly (over twice as many) in the overview display condition. Table 2 shows the transitions from problem (p) to action (ac) and from state identification (st) to general query (gq). The transaction from problem (p) to action (ac) was found to be significant ($p<.05$). However, the transitions from problem identification to action were borderline significant ($p<.1$).

Transition	Display	No Display
P to A	22	8
ST to GQ	31	16

Table 2. Number of transactions.

4. DISCUSSION

It was hypothesized that an overview display would trigger more situation assessment behavior. The greater number of verbalizations in the overview display condition was consistent with that hypothesis. This was in spite of the fact that subjects in the no overview display condition had to make additional verbalizations to ask for the values of the four high level variables. Subjects also had better awareness of the state of the city in the overview display condition. This indicated an improvement of subjects' Sass (the perception and interpretation of city state) due to the presence of the overview display. The overview display also helped in identifying problems and taking the appropriate action (as indicated by the higher number of direct transitions from the problem to action verbalization categories). This indicates that the overview display tended to shorten the distance between perception and action. This could be important in abnormal or emergency situations where quick action is required.

The overview display led to more situation assessment, more awareness of trends, and an increased number of transitions from problems to actions. While these results refer to verbalization data only, it is likely that they also reflect actual performance, since the verbal protocols were made in the context of acting as a supervisor and instructing an "operator" to actually carry out the requested actions on the simulation software.

These results demonstrate the usefulness of verbal protocol analysis in assessing the effectiveness of new display technology in a complex task. They also demonstrate the sensitivity of situation assessment

behavior as an indicator of the effects of display technology (overview displays in this case). This method seems particularly appropriate in the analysis of new display technologies in nuclear power plants where it is routine for a supervisor to be giving verbal instructions to one or more operators working at the control interface.

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