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First published in:
Technische Universität, Dresden, 1990, Mental Work and Automation, Bd. 6, S. 100 - 105

VISUALIZING USER INFORMATION IN THE INTERFACE: EFFECTS ON EXPLORATORY LEARNING AND PERFORMANCE

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1. Introduction

Visualizing user information in the interface has become one of the most preferred modes of information design. Visualization of system states or command options is a salient feature of interfaces which can be manipulated directly by means of a mouse or other analogue input devices (cf. Shneiderman, 1982). In direct manipulation interfaces the user is supported by menues, icons, windows, and indicators for different purposes. This information is designed to facilitate memorizing and recognizing command names, parameters, file names or syntactic rules. Especially the advantage of recognition over recall is emphasized (cf. Shneiderman 1980). According to Hutchins, Hollan and Norman (1985) visualized user information diminishes the semantic and articulatory distance between the users' goals and the realization of these goals in terms of the interface language. Whereas on the basis of these general theoretical considerations positive effects on learning can be expected, empirical evidence is not unequivocal: Roberts and Moran (1983) compared user performance with nine text editors and found the direct manipulation systems to be superior. Whiteside et al. (1985) tested user performance with command, menu, and iconic interfaces and stated poorer results for the direct manipulation interfaces. According to Altmann (1987) this contradiction may be due to the small number of training sessions. In her study subjects were trained for seven sessions on Wordstar (MicroPro) or MacWrite (Macintosh). Subjects using MacWrite - a program with a high degree of visualization - showed faster task processing and more complete solutions, even in a transfer task.

Most of these studies compared ease of learning in entirely different systems. Such overall comparisons do not allow to attribute differences in user performance to distinct factors because other aspects (e.g. different functionality) may be confounded with effects attributed to visualization. Therefore, in some studies, different versions of the same system were compared. Widdel and Kaster (1987) e.g. reported a promotive effect on

This research was supported by Siemens AG. My thanks are due to Prof. Dr. W. Schönpflug for his helpful comments on a previous version of this paper.

learning in subjects who saw the whole menu structure on a second screen. An even more detailed study was conducted by Arend (1989) on an experimental database system. He visualized either all commands or only a subclass depending on the previously selected command. In order to control for the complexity of visualized information, the commands used were either elementary operations or functional complex commands. The result: Simultaneously available elementary operations are favourable, but only if they are completely visualized. For technical reasons not all information can be visualized simultaneously. Usually information is organized hierarchically so that only top-level information has to be displayed whereas other pieces of information are "hidden" under the system's surface. So high-level information serve as an address for low-level information. The efficiency of an address depends on its semantic content and on the preciseness with which it refers to further information (cf. Schönpflug, 1989). Therefore, not only the amount of visualized information has to be taken into account but also its semantic content.

But there is still another problem relating to the evaluation of visualization: User performance is not only affected by the interface design but also by the teaching and training method (cf. Frese, Schulte-Göcking & Altmann, 1987). The above mentioned studies used the same teaching procedure for all types of compared interfaces, thereby neglecting that the given training method may be more or less compatible with different interface types. Information deficits caused by poor interface design e.g. may be compensated by user-initiated learning activities if the user has the opportunity to explore the functions she or he feels uncertain about. Deficiencies in information design should be reflected in the user's activity to obtain missing information or to reduce uncertainty. Such effects would only be observed if there are sufficient degrees of freedom in the training procedure. One goal of the present study is to investigate this interaction of visualizing user information with training requirements.

2. Method

To study this hypothesis in more detail an experiment was designed in which not only task performance but also the self-paced learning activity during free exploration served as a dependent variable. As independent variables the amount and semantic content of visualized user information was manipulated. Within this experiment the subjects had to learn the commercially available text editor MS-WRITE. WRITE is a direct manipulation system employing a one-finger-mouse and hardkeys. At the highest level there are 41 commands available, organized in six pull-down menues.

Experimental design: There were two factors with two levels each. With the first factor the amount of visualized user information was manipulated: Half of the subjects had a figure above the screen displaying all 41 commands and their correspondence to the six menu names. The other half had no such help. In that group commands could only be visualized by opening a menu. In both groups it was impossible to open more than one menu at the same time. With the second factor the semantic contents of the menu names was varied: One half of the subjects had the menu names of the original system such as "Data" "Searching" "Symbols" or "Text". The other half had semanticly neutral menu names (digits 1 to 6). Crossing both factors yields four experimental groups:

- semanticly relevant names / menu figure (RN/MF)
- semanticly neutral names / menu figure (NN/MF)
- semanticly relevant names / no menu figure (RN)
- semanticly neutral names / no menu figure (NN)

With respect to all other features the system was identical in all groups.

Procedure: There were five sessions of approximately 2 hours each, for five days running. The sessions consisted of different phases: (1) In the beginning of sessions 2 to 5 the knowledge acquired in the preceding sessions was tested: The subjects had to answer questions concerning properties of the system and its functions (knowledge about facts) and concerning the sequence of operations to attain certain goals (knowledge about actions). At this time subjects had no access to the system. After answering the questionnaires the subjects had to solve tasks which required the application of all formerly instructed procedures. (2) New instructions: In sessions 1 to 4 the subjects had to go through written material explaining new functions. The instructions were designed to execute each step immediately with the system. (3) Exploration: After each new instruction the subjects were allowed to explore all functions for ten minutes. All subjects were instructed and tested individually. In session 5 there was only a test phase but no new functions were learned. In addition to the test task the subjects had to perform a transfer task in this session. The transfer task's solution required procedures which had not been part of prior instructions. In the end of the last session it was tested how the subjects remembered the screen layout - especially the menu system - as an image, not in terms of verbal memory. Therefore knowledge of the screen layout including the locations of all commands was tested by means of a nonverbal method: In the last line of a blank screen all 41 commands were displayed successsively. The subjects had to point with the mouse to the place were she or he supposed the command was located in the original system. There were no retrieval cues available.

Subjects: 29 computer novices aged from 17 to 53 years with a mean age of 26. The 14 female und 15 male subjects had passed different vocational trainings ranging from academic to technical and administrational qualifications. They were paid for their participation. There were no group differences concerning age or measures of intelligence.

3. Results

Exploratory Behaviour: The analysis (two ANOVAs with four repeated measures) of the subjects' behaviour during the exploration phases yielded the following results: Subjects without menu figure (RN, NN) opened more often menues ($F(1,22) = 7{,}18$, $p < .05$) and explored a greater number of different functions ($F(3,66) = 2{,}76$, $p < .05$). The last effect is an interaction of "Menu Figure" with the within-subjects factor "Session" showing a stronger increase of exploration especially in group RN.

Verbal knowledge: Errors in the questionnaire "Knowledge of Facts" were standardized for the number of items in each session. An ANOVA revealed an interaction effect ($F(3,75) = 4{,}10$, $p < .01$) of the factors "Menu Figure" and "Session": Both groups who learned with the menu figure performed worse than the other two although they started with fewer errors in the first test. A post-hoc classification in three groups exploring the system with low, moderate or high intensity confirmed the correlation of exploration and quality of verbal knowledge: Intensively exploring subjects committed the fewest errors in both questionnaires ("Knowledge about Facts": interaction of "Exploration" with "Session", $F(6,78) = 2{,}85$, $p < .05$) ; "Knowledge of Actions": main effect "Exploration", $F(2,26) = 4{,}73$, $p < .05$).

Spatial knowledge about the locations of commands: The mean deviations (x-dimension) between the real locations of commands and the positions the subjects pointed to was greater in the groups RN/MF and NN/MF (main effect of the factor "Menu Figure": $F(1,24) = 4{,}90$, $p < .05$). With respect to the x-dimension the spatial representation of the menu system seems to be more exact in the groups learning without menu figure. A comparable effect for the y-dimension was not found.

Task processing: Experimental effects concerning the way the participants solved the task could only be found in the first test task. Again there was a main effect for factor "Menu Figure" ($F(1,24) = 5{,}04$, $p < .05$) concerning the mean number of actions used to solve the tasks: Learning with the menu figure helps to find equally complete task solutions requiring less steps. This is in line with another main effect ($F(1,24) = 6,36$, $p < .05$) of the same factor in the number of errors in executing subactions. Subjects learning with the menu figure performed better with respect to execution errors, but only in the first measure. But the contrary was found for the correction of planning errors (planning errors are subactions executed correctly but aimed at a wrong goal or subgoal). Both groups having no menu figure compensated in the first test task more planning errors than the groups RN/MF and NN/MF ($F(1,24) = 5,90$, $p < .05$). As the number of planning errors itself did not differ between the groups this result demonstrates a higher problem-solving competence in subjects working without menu figure. This effect became clearly appearent in the first task and was marginally replicated in the transfer task.

4. Discussion

The initial hypothesis that visualization of user information may affect learning activity was strenghtened although group differences could only be found with respect to the amount of visualized information: Less visualization led to more intensive exploration. Even more important is the result that groups learning with less visualized information (but exploring more intensively) performed better in a test of verbal knowledge and corrected more planning errors. This may be due to a "levels-of-processing-effect": These subjects not only compensated missing information, they even acquired more relevant knowledge than the groups being provided with more visualized information. Interestingly enough, even spatial knowledge of the locations of commands is more strongly controlled by breadth and depth of learning activity than by the actual presentation of the menu figure which represented all locations directly. On the other hand, execution of already known and correctly planned subactions is supported by the visualization of commands. This result is in line with Arend's (1989) result that especially the complete visualization of elementary operations enhances performance.

The manipulation of the semantic content of the visualized information surprisingly did not yield any significant differences between groups. This may be due to a considerable heterogeneity among the six menues. Preceding classification studies had shown that there were severe differences in menu composition and in quality of the names used in the original WRITE-system. Concerning those menues which had a good semantic fit between name and contents, positive effects on learning could be found. But these effects do not appear in the above reported analyses which included all menues.

Two general conclusions may be drawn from these results:

(1) Evaluating interface design empirically requires either to manipulate instruction and training methods systematically or to regard self-paced learning activities as a dependent variable.

(2) Providing the user extensively with visualized information about system states and command options may affect explorative behavior and thereby even impair problem solving competence whereas the execution of correctly planned routine operations may be supported by providing appropriate retrieval cues.

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