Optimum Display Arrangements for Presenting Visual Reminders

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Developments in technology now allow designers to make use of a wide variety of layouts to present material at an interactive terminal. Our understanding of perceptual and cognitive processes shows that various tradeoffs will need consideration in evaluating such layouts (availability of material vs screen clutter; reliance on user memory vs use of reminders etc). We approach these through the framework of attentional switching.

We shall report an experimental study which evaluates these tradeoffs in a frequently encountered text editing situation. Our editor may be set to either 'insert' or 'overtype' mode. This information can be displayed with varying prominence in a peripheral window on the screen,
displayed as a change of cursor, or omitted from the screen display. We have monitored user interaction at a keystroke level during text editing sessions and show that the different forms of presentation of reminder information can result in substantial differences in performance.

Keywords: Visual displays, windows, attention allocation, peripheral vision, reminders

1. Introduction

Interactive computing with visual display units is rapidly progressing from a situation in which the VDU was employed simply to present sequential text to a situation where the full potential of the technology may be exploited so as to distribute information at a variety of different screen locations. In particular, windowing tools are becoming widely used as a design aid in planning interfaces. Our aim in this paper is to suggest ways in which psychological knowledge of the visual, attentional and memory systems can be directed to this application, and to present a pilot study showing how the concepts may be amenable to experimental investigation. The first part of the discussion is rather more general than the specific issue which we finally home in on, which concerns the presentation of visual reminders.

2. Activity with interactive displays

Window based interfaces allow the possibility of presenting a number of separately addressable virtual screens within the confines of a single physical screen. Furthermore, any one of these virtual screens can, in principle, be used to gain access to further displays. One way in which such a potential can be exploited is to allow a user to switch between different tasks. A second type of use is to present different sources of information relevant to a single task at different locations on the screen. In this paper we concentrate on the latter, but it must be recognised that the distinction between the two is by no means rigid. Most single tasks can be subdivided into components. We are aiming to produce a framework for a task analysis of this type of interaction. It is recognised in the study of task analyses that a variety of different hierarchical levels may be considered. Our analyses consider a low level in the hierarchy, the fine structure of user actions. However we have been struck by the extent to which some of the concepts would seem to be useful for consideration of higher levels also.

The seminal keystroke analysis of Card, Moran and Newell (Card,
Nervell (Card, Newell & Norean [1983]) showed that certain activities, most notably text editing, could be rigorously analysed into an elementary detailed sequence of operations. A limitation of their approach is the concentration on a single goal-oriented processing stream. A feature of human cognitive activity which becomes of increasing importance when more complex display layouts receive consideration concerns the fact that much processing occurs outside the main conscious processing stream. Work on the psychology of human attention currently offers a model of human operation in which activity (thought or action) in one principal processing stream may be accompanied by activity in several subsidiary processing streams. Attention is seen as a flexible resource with tasks which are overlearned and/or of minimal information content proceeding in an automatized fashion at the same time as an individual engages on a principal task.

This concept can be clearly illustrated from a consideration of the use of vision. Our eyes take in visual information from a wide area of the visual field. At any instant, the gaze is directed to one particular location. Visual resolution is highest at this location and decreases at points away from this location in a very systematic manner. Normally, it is the visual material to which the gaze is directed which receives focal attention. Nonetheless, visual processing outside the active region is still occurring. For example, any substantial change will be capable of eliciting an orienting response wheresoever it may occur in the peripheral visual field.

Intensive investigation of the reading process (Rayner [1983]) has expanded our understanding of how parallel processing is used dynamically. Detailed textual information is taken in from a quite small region (around 7 characters) where the gaze is directed. But less detailed information (word boundaries, initial letters of words etc.) is also being simultaneously assimilated from more distant regions to assist in eye guidance and provide some preliminaries to the detailed analysis. This information is taken in from a wider region, extending in an asymmetric manner further to the right of the fixation point than the left. It appears that certain discriminations in parafoveal and peripheral vision can be made at no cost to the attentional resources required for central processing, whereas other discrimination can be made only if some conscious effort directs attention to the peripheral location (Treisman [1985]). Under normal circumstances, direction of attention to a peripheral visual location would involve direction of an eye movement to that location although the two operations are partly dissociable (Shepherd, Findlay & Hockey [1986]).

Miyata and Norman (Miyata & Norman [1986]) have emphasised the need to take account of multiple processing streams when considering
the potential of window based systems. Of course, such multiple streams may be occurring both on the human and the machine side of the interface. In general, for the operator, one particular stream will be occupying the current focus of consciousness (although not necessarily exclusively) and a key aspect of activity becomes a consideration of how this focus shifts from one stream to another. Surprisingly little seems to be understood of this aspect of cognitive functioning. A profitable analogy, drawn again by Miyata and Norman (Miyata & Norman [1986]), is with the ‘interrupt handling’ used in computer function.

Consider as a working hypothesis the idea that conscious human activity can be viewed as consisting of bouts of ‘processing’ which are ended at an ‘interrupt’. Interrupts may obviously be generated externally through the senses – a telephone call, the arrival of a visitor. However the interrupt idea seems to have some face validity as a description of internal causes of processing terminations as we discuss in the following section. The ‘pop-up’ occurrence in memory of a task requiring urgent attention is an example.

Situations arise in which interrupts are deliberately preset as reminders in order to ensure that a particular task is accomplished. The topic of reminders can link the abstract study of attention and processing streams with practical design considerations since the provision of reminders is rendered feasible by a multi-element display. However, a reminder is also, by its nature, a distractor and its value may vary accordingly. There are times when reminders may be more welcome than others. It is not difficult to point to situations in which human activity is hindered by an overabundance of interrupts. These may be external (the telephone never stops ringing), but lack of concentration seems also characterised by the appearance of too many distracting thoughts from memory. Such situations may be contrasted with the low level of interrupts characteristic of an individual ‘lost in thought’, perhaps engaging in a search for inspiration.

3. Internal and external memory

The topic of reminders shows the intimate connection between the topics of attention and memory. A reminder is essentially a memory aid and memory aids are widely used in a wide variety of situations. If we need to remember what to buy when we visit a shop we often take a list. External aids to memory are often employed when other, intervening, cognitive events might interfere with the processes of learning and recall, when accuracy is at a premium, and when memory load is to be minimised to facilitate the allocation of attention to other activities. It seems that, in general, individuals prefer to use external aids to memory rather
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4. State monitoring

A characteristic of a complex system is that it can manifest a variety of different ‘states’ and as systems grow in complexity, the number of possible states is also increasing. When interacting with a complex system, the problem of how to ‘keep track’ of the current state of the system may be termed the ‘state monitoring’ problem.

We have concentrated on one rather common situation in which state monitoring is necessary. Many word processors and text editors have available two or more modes that may be used for inserting text. Typically there is an insert mode in which new text may be entered without deleting any existing text as an alternative to an overwrite mode in which new text is typed over existing text. Experience shows that both facilities can be useful at different times and commonly it is possible to switch from one mode to another with a simple command or keypress.
We can use this situation to illustrate the choices that occur at the fine structure level when designing an interactive system. From the user's point of view, we are looking at a place where a processing stream is interrupted: new information must be obtained about the system state before the next task – the text insertion – is carried out. As just discussed above, both psychological theory and evolved design practice suggest that in this particular case external rather than internal memory should be used. How then can this information be presented on the screen?

We were led to this question through experience with a particular text editor in which such information was presented at the top right edge of the screen in the same font as the remainder of the text. To use the information, it was necessary to look at it. Thus the routine for 'interrupt handling' took the following form: make a saccadic eye movement to the appropriate screen location; retrieve the information; find the text position (flashing cursor); make a saccadic eye movement back to the text position. We have coined the term 'minimum switch' to describe this sequence, and we can contrast it with both more and less extensive interrupt handling operations as follows:

1. **Normal switch**: Used to obtain information which is not immediately available on the screen. For example, a sequence of mouse operations could be used to open a window to obtain the information.

2. **Mini switch**: (as described above): Used to obtain information that is available on the screen but not at the central viewing location. To obtain the information it is necessary to move the eyes to the screen location.

3. **Micro switch**: Information could be presented in the visual periphery which has sufficient salience for an overt eye movement not to be required to extract it. It is probable that some attentional cost is still involved.

4. **Information at the fixation point**: It would seem that if a state indicator could be made available close to the fixation point, even less attentional capacity might be required for its use.

Analysis of the component activities shows that fewer actions are required as the list is descended. We may expect that the elimination of actions will lead to faster and, perhaps, more easily used, systems. In the subsequent sections we discuss an experimental study we have embarked on to test our intuition that the different ways of presenting reminders discussed above will differ in the attentional demands made on subjects. At the present time, only results from the early stages are available.
Optimum Display Arrangements

5. Method

5.1. Subjects

Twelve University students aged from 20 to 23. All had some experience of the screeneditor used by the University mainframe computer (NUMAC). Records from a further seven subjects were unfortunately lost due to a problem with the monitoring system. The subjects' typing skills ranged from poor to very good. The subjects were divided into two groups with typing abilities roughly balanced between groups.

5.2. Design

Our aim was to compare performance when state monitoring required a 'Minimum switch' (No. 2 above) of a saccadic glance to a peripheral location with that when information was available at the fixation point (No. 4 above). To this end we constructed several modified forms of the screeneditor program which could be run on an IBM PC. All the modified programs allowed the user access to a restricted command set. Forward and backward scroll commands, cursor movement commands, character and line deletion commands were common to each version of the program. Three different versions of the program all used the same pair of control keys for switching between 'character insertion' and 'line insertion' modes (these modes were mutually exclusive). In the former case, characters could be inserted in the middle of the text: in the latter characters entered would overtype existing material unless a new line was entered. The versions differed as follows:

Version P: An indicator was presented in a one-line window on the top left of the screen to indicate which of the two insert modes was current. A solid block line separated this window from the remainder of the text.

Version C: The mode indication was achieved by a change in cursor character. In line insertion mode, the cursor was a solid block (■). In line insertion mode, the cursor was changed to a pair of bars (ー). In each case the cursor flashed at the standard rate.

Version E: Both the indicators described above were available.

Version P was similar to the standard version of the screeneditor with which the users were familiar (although on the majority of terminals this displayed the mode information on the top right hand side of the screen and the line delineating the window was thinner).
Both groups of subjects carried out two sessions of text editing as described below. The first session was with editor Version E and was identical for both groups. Group A carried out the second session with editor version P and Group B with editor Version C.

5.3. Stimulus material and procedure

Two texts were prepared in advance. The texts were taken from a book of humorous letters and comprised about three A4 sides. Files containing two degenerate versions of these texts were prepared for the PC, in which a large number of errors were deliberately inserted. These were prepared so that their correction would be most simply achieved by frequently switching between line and character insertion. The number of corrections to be made was the same in both texts. A printout of the correct version of each file was made with the errors requiring correction highlighted in yellow (for character insertion requirements) and orange (erroneous letters where overtype gave the simplest means of correction).

Each subject was tested individually in two sessions. In the first session (Editor Version E), the operation of the text editor was explained to the subject and attention drawn to the two forms of mode information. In addition an instruction sheet giving the operations of the various control keys and the significance of the cursor change information was also available for consultation. Following this instruction period, the subject was given the printout and asked to use the editor to make the necessary corrections in the computer file.

5.4. Monitoring of user interaction

The editing sessions were recorded with the UMIST MMI Monitoring System (Morris et al. [1987]). This is a flexible tool which provides a time stamped record of keypress and mouse activity on (in our case) an IBM PC. The machine consists of a microprocessor with 1MByte of RAM which interfaces via a communications board which has RS232 connections to the user machine. The data record is supplemented by a 'journal' file into which various information can be entered (e.g., indications that some particular activity took place during the session). We made use of the journal record in the preliminary session to indicate the point at which the experimenter handed control over to the subject.

The data record can be subsequently either analysed or used to form a session replay in which the user machine is 'driven' by the recorded data to replicate exactly the original sequence of operations (provided of course that the user machine starts initially in the same state). In this study we used a journal marker to indicate when the subject's activities commenced. The timing data were analysed from this marker. For the
data on detailed errors etc. it was necessary to replay and observe the record as the software for automated analysis was unavailable.

6. Results

6.1. User strategies and comments

The initial comments of the subjects when the cursor indicator was explained occasionally expressed doubt about the arbitrary nature of the indicator. However, most of the subjects experienced no difficulty in acquiring the relevant discrimination and one later volunteered the view “it’s obvious which one is which”. All subjects shifted between modes: one, however (Group B: Subject 4), used the strategy of typing a control character sequence before every correction, even when this was redundant. This strategy avoided the need for state monitoring although would not be useful on a system where a state change is of the toggle switch type.

Subjects in Group A who did not have the cursor information in the second session reported generally that its loss was felt and they had to think more about which mode they were in. Most subjects in Group B who had the peripheral information removed reported that they had learned to use the cursor information in the first session and there was no effect of the change. One exception (Subject 3) needed to refer to the instruction sheet at the beginning of the second session, but very quickly began to use the information.

These comments suggest that even the minimal switch of consulting a peripheral indicator requires appreciable processing effort. The superiority of the cursor information was supported by more objective analyses.

6.2. Time taken for the editing task

Table 1 (below) shows the times in minutes taken by each subject for the two tasks, and also the ratio of the two times.

The difference in editing times largely reflects the differential typing and computing experience of the subjects. However, it is possible to make a comparison which minimises the effect of these differences by using the subject’s performance on the first tasks as a baseline measure. The ratio measure uses this baseline and shows that Group A show a much greater improvement in the second task. This result is however not statistically significant ($t = 1.69 : 10 df \ p \approx 0.1$) although it seems possible that a larger subject group might well reveal the effect to be a genuine one.
Table 1.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Task 1</th>
<th>Task 2</th>
<th>Perc.</th>
<th>Subject</th>
<th>Task 1</th>
<th>Task 2</th>
<th>Perc.</th>
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<tr>
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<td>38.02</td>
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<td>12</td>
<td>65.97</td>
<td>48.83</td>
<td>74.0</td>
</tr>
</tbody>
</table>

Mean 95.0 Mean 77.4

6.3. Errors and pauses

The number of mistakes left in the final copy did not differ significantly between the two groups (Group A Session 1: 1.2 mistakes average, Session 2: 1.3 mistakes average. Group B Session 1: 2.6 mistakes average, Session 2: 3.3 mistakes average), nor did the number of typing errors made during the sessions (Group A Session 1: 11 average, Session 2: 10.3 average, Group B Session 1: 17 average, Session 2: 11.8 average). The number of occasions a subject was in the wrong mode (as evidenced by a later correction) was as follows: Group A, Session 1: mean 4.3, s.d. 3.2, Session 2: mean 4.3, s.d. 2.1, Group B, Session 1: mean 5.7, s.d. 3.2, Session 2: mean 3.2, s.d. 1.5). Group B shows an improvement in performance which is not shown by Group A, but the difference is not significant statistically \( t = 1.58, 10 \text{ df} \).

A measure was also taken of pauses occurring before mode changes. A pause was assessed for this purpose as a noticeable delay with no cursor movement during fast replay (equivalent to a pause of about 3 seconds in real time). In Group A the number of pauses increased between sessions (Session 1: mean 8.0, s.d. 1.5, Session 2: mean 10.7, s.d. 6.0). In Group B, on the other hand, the number of such pauses decreased between sessions (Session 1: mean 7.0, s.d. 2.8, Session 2: mean 4.3, s.d. 1.5). The difference between the groups is statistically significant \( t = 3.2, 10 \text{ df}, p < 0.01 \). It must be noted that this latter analysis contains an element of subjectivity in the assessment of pauses: we are currently working to replace this measure with an objectively analyised equivalent.

7. Discussion

Our results appear to support the contention that the two methods of providing state information were differentially effective. However this result must be interpreted with some caution. Firstly, although all
in the final copy did not differ significantly in Group A Session 1: 1.2 mistakes average, Group B Session 1: 2.6 mistakes average, Group A Session 1: 11 average, Session 2: 17 average, Session 1: 2.6 average). Subject was in the wrong mode (as evidenced as follows: Group A, Session 1: mean 4.3, 4.3, s.d. 2.1, Group B, Session 1: mean 5.7, Group B shows an improvement shown by Group A, but the difference is not 1.58, 10 df). of pauses occurring before mode changes. A purpose as a noticeable delay with no cursor delay (equivalent to a pause of about 3 seconds A the number of pauses increased between 8.0, s.d. 1.5, Session 2: mean 10.7, s.d. 6.0). On the other hand, the number of such pauses decreased 1: mean 7.0, s.d. 2.8, Session 2: mean 4.3, between the groups is statistically significant 1). It must be noted that this latter analysis subjectivity in the assessment of pauses: we are not in the use of this measure with an objectively analysed support the contention that the two methods of analysis were differentially effective. However this was done with some caution. Firstly, although all the differences pointed to the greater usefulness of the cursor change indicator, only one difference was significant. We plan to run further subjects in place of those whose data was lost. Another concern is whether our results might be influenced by the demand characteristics of the experimental situation. We deliberately chose a design which would compare the cursor indicator with the indicator which would have already been familiar from previous use of the screenditor. However it is possible that the novelty of the cursor manipulation, coupled with an experimental design in which we were obviously emphasizing mode changes, may have resulted in differential motivation between the two groups leading to differences in performance unrelated to the screen changes.

Nevertheless the most plausible interpretation of the results would seem to be along the lines of the attentional differences that we have outlined in the introductory sessions. Russo (Russo [1978]) pointed out that the use of eye movements in scanning is likely to be accompanied by a cognitive cost in terms of both the execution time and the preparation time for the activity. We believe that designers should give more careful consideration to these aspects. If our results are substantiated by further investigation, they indicate that it may pay dividends to explore how extensively cursor information can be developed. Although there are clear limits to the information that can be provided with cursors, there are still many possibilities (colour, patterns, blink rate) which could be explored. Conveying information in this way will certainly be less conventional than current practices; however such possibilities will certainly merit consideration in the course of a technological revolution which may well be of similar significance to the invention of writing.

References


