

Remembering While Mousing: The Cognitive Costs of Mouse Clicks

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MEASURING COGNITIVE COSTS

Thinking harder, attending more carefully, remembering more or for longer periods are activities that all contribute to the mental overheads that may have to be met when working with computer displays. One way of measuring these cognitive costs is by providing users with tools (e.g. memory aids) and then seeing how features of the interface influence the way people use these tools. In some respects this is like providing a hiker with a walking stick; the stick may not be used much until the going gets tough. This technique was developed in order to explore the memory load people experienced when working with a document on a computer screen. The practical issues concern saving space on the screen by removing some of the information that readers will need only intermittently but leaving the material accessible, just a mouse click away from the current screen display. The scientific issues concern the memory processes involved when people are working with indexes or menus that have to be summoned into view by clicking a button on the screen.

The task chosen was familiar: comparing prices in order to decide where to make particular purchases. In such tasks people have to remember the products to look for, the vendors whose prices they wish to compare and the prices once found. This can be a lot to remember and people may need to support or jog their memories in a variety of ways – such as by making notes of the prices or by re-reading their shopping list.

Two series of studies were carried out. Both involved an on-line document having a table of contents from which readers could access price lists. In the first series of studies this contents list was either shown below the price lists (so requiring

more screen space) or readers could click a button on the screen to toggle between the contents list and other pages. It was predicted that readers would use more memory support when the contents list had to be summoned into view. In the second series of studies alternative menu displays were provided for accessing price lists. These menus differed in whether they were always visible on screen or whether the menu options were displayed only when readers clicked on the menu name. Again it was predicted that people would use more memory support if working with menu items that had to be summoned into view.

EXPERIMENT 1: USING AN INDEX

The Task

Readers used an on-line document to decide where it would be cheapest to purchase the products on different shopping lists. The length and complexity of the shopping lists was varied by specifying either 1 or 2 products in one, two or five shops (e.g. the question “*Is it cheaper to go to Ainsby or Desco to buy a small pack of frozen Coley fish and a tin of Fusscat salmon?*” specifies two shops and two products). Carrying out the task consisted of answering 18 questions by reading the question, finding and comparing the prices, returning to the question and selecting the multiple-choice answer; then repeating this cycle for the next question. The task took about an hour to complete and was preceded by several minutes practising point-and-click movements with the mouse.

Materials

The document was created in HyperCard™ and presented on an A4 monochrome monitor using an Apple Macintosh 11ci. The text gave price details for 16 product categories (e.g. soft

drinks, frozen fish, tins of soup) in five fictitious stores. Readers moved from one part of the text to another to display the price lists for these product categories by clicking buttons on the screen. Readers could either click a cell in the index table (see figure 1) or select another shop from the names at the bottom of the screen or select a new section within a shop from the options shown alongside the price lists (see figure 2). Clicking a shop name displayed the price list for dairy products in that shop (this corresponded to the top row in the index table), whereas clicking the *Hop* button underneath a shop name displayed the price list for the same products as currently shown on screen but in the new shop.

Half the people taking part in the experiment had a two-window display with most of the information (the price lists, questions and notebook) being shown in the upper window and the index table in the lower window. The other people worked with a single window display. Here the index table could be summoned by clicking a button labelled *Index*. When displayed, the index table completely hid the price list.

Memory Support

Readers were given an on-line notebook for recording prices. Figure 2 shows that the notebook had two associated buttons *Add* and *Look*. After clicking the *Add* button, clicking any price on the screen would add it to the notebook. The price being entered was shown below the *Add* button so that people could know they were entering the details they intended. After several prices had been added, the notebook might look as shown in figure 3. The notebook automatically started a new page for each question. On every screen page was a *Question* button that let people re-read the question if they forgot what they were looking for. Pages also had a *Return* button that would take readers back to the preceding screen display.

Figure 1. The index table showed product categories for 5 fictitious stores. Price lists could be accessed by clicking on any cell in the table.

	Ainsby	Budget	Cutcost	Desco	Ecobuy
DAIRY	Cheese	Cheese	Cheese	Cheese	Cheese
	Marg	Marg	Marg	Marg	Marg
	Milk	Milk	Milk	Milk	Milk
	Yoghourt	Yoghourt	Yoghourt	Yoghourt	Yoghourt
DRINKS	Beer	Beer	Beer	Beer	Beer
	Soft	Soft	Soft	Soft	Soft
	Spirits	Spirits	Spirits	Spirits	Spirits
	Wines	Wines	Wines	Wines	Wines
FROZEN	Fish	Fish	Fish	Fish	Fish
	IceCream	IceCream	IceCream	IceCream	IceCream
	Meat	Meat	Meat	Meat	Meat
	Puddings	Puddings	Puddings	Puddings	Puddings
TINS	Fruit	Fruit	Fruit	Fruit	Fruit
	Pet Food				
	Soups	Soups	Soups	Soups	Soups
	Veg	Veg	Veg	Veg	Veg

Readers

28 adult volunteers from the panel of the MRC Applied Psychology Unit were paid for taking part. Their ages ranged from 21 to 59. The mean age of those working with the two-window display (index shown below prices) was 43 years and those working with the single window (index summoned from behind prices) was 42 years.

RESULTS AND DISCUSSION OF EXPERIMENT 1

Memory Support

Analysis of the number of questions (max=252) on which people used the notebook and the number of questions they re-read while checking prices, showed that people more often used memory support with the single window (they made notes on 64% questions, re-read on 40% questions) than with the two-window display (notes on 44% questions, re-read on 31% questions). The data are summarised in more detail in the first two rows of Table 1 where it can be seen that use of memory support varied with question difficulty and, as one would expect, was much greater on 2 product questions than on 1 product questions. But for both kinds of question, people working with the single window used memory support more often than did people working with two windows. The difference between the groups was statistically significant on all three rows – i.e. for the easier 1 product questions (Student's $t=2.86$, $p<0.01$), for the harder 2 product questions ($t=2.19$, $p<0.05$) and when pooling across all questions ($t=2.69$, $p<0.01$).

Index use

People having two windows often used the index to access price lists (71% questions). This was not the case for those working with the single window, where the index had to be summoned and was used on only 29% questions (Student's

$t=4.93, p<0.001$). When the index had to be summoned with a click, people more often used the menu options visible on screen for accessing price lists. This difference between the groups might not matter if it had no cognitive costs, but the greater use of memory support by those preferring the menus suggests that there may have been overheads. Certainly using the menu could sometimes involve three clicks where the index would need only two.

Why did people ignore the index?

Perhaps readers felt they might lose their place if they summoned the index or perhaps they were reluctant to make an extra click in order to display the index. To examine these possibilities a further study was undertaken with the two window display in which the index in the lower window was covered with a "door" that opened when readers clicked on it. Now readers could see that the index was available and they could use it without losing sight of the page they had been reading, but the effort of an extra click was still required.

Data were collected with the help of another 14 paid adult volunteers (mean age 42.4 years). The performance of people having the closed door over the index was found to be similar to that of the previous single window group. They took notes on 59% questions, re-read the question on 38% questions and used the index to access prices on 37% questions. Table 1 shows how similar the closed door and single window groups were in using memory supports for different kinds of question. However, the differences between performance with the original two-windows and with the closed door display were only reliable statistically on one-tailed tests and not for 1 product questions (2 product questions: $t=1.78, p<0.05$; all questions: $t=1.81, p<0.05$).

Table 1: Number of questions that were reread + number on which notes made. (* = $p<0.05$; ** = $p<0.01$)

	1 product	2 product	All Qns
2 windows: Index below	44	145	189
1 window: Index behind	** 84	* 180	** 264
2 windows: Index + door	65	180	245

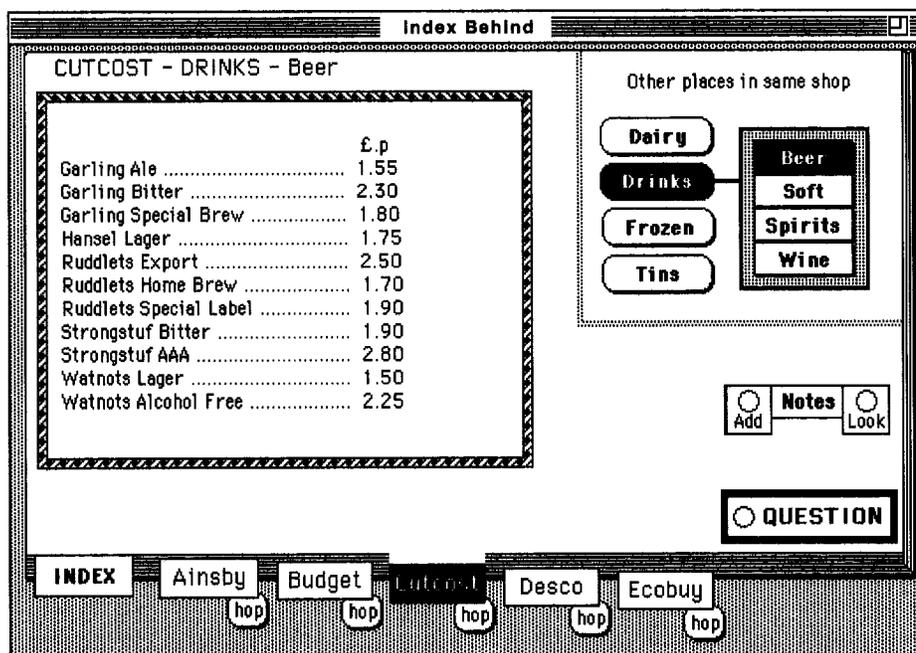
These data from the display with a closed door over the index suggest that much of the cognitive cost when working with a single small window appears to have come from the action of making a click to access the information wanted. However, caution is necessary because people were also selecting different ways of locating price lists. This problem could be circumvented by making a similar comparison for the menu options, which many readers chose in preference to using the index. Experiment 2 did this by varying the interface for the menu system.

EXPERIMENT 2: USING MENUS

Materials

The shopping task was similar to experiment 1 with the single window display. As well as supporting memory by helping readers return to the question and providing a notebook, there was a third memory aid, a destination planner. However, people chose to use this planner on only the most difficult questions and so it will not be further discussed here. The use of

Figure 2. A price list. Other price lists could be accessed by clicking shop names or the buttons under "Other places in same shop". The hop button displayed prices for the products shown on screen but for the selected shop.



the notebook was simplified by removing the *Add* and *Look* buttons. When any price was clicked it was shown below the price list and added to the current page of the notebook. Clicking the notebook button displayed the current notebook page. The *Return* and *Question* buttons worked as in experiment 1.

Two different menu interfaces were created for accessing price lists. One interface had the menu options always visible on screen and was similar to that used in experiment 1 but the *Hop* button was removed and hopping was made the default condition when a shop name was clicked. The other menu interface saved space by showing on screen only three screen buttons labelled *Stores*, *Sections*, *Shelves*. When readers clicked one of these buttons further menu options dropped into view below that button (see figure 4) and remained in view until another menu option was selected. Readers made essentially the same decisions with both menu styles but they had to make an extra click to access the menu options when these dropped down.

Readers

24 female adult volunteers from the subject panel of the Applied Psychology Unit were paid for their help. Their ages ranged from 18 to 50 years. Half worked with each of the menu systems. The mean age of those having menus that were always visible was 33 years and of those with drop down menus was 38 years.

RESULTS AND DISCUSSION OF EXPERIMENT 2

Memory Support.

People re-read the questions significantly more often when they were working with drop down menus (57% questions) compared with menus that were always visible (39% questions) (Student's $t=2.30$, $p<0.05$). These findings are consis-

tent with those of experiment 1 in showing that there can be cognitive costs to saving screen space by removing some of the information even though it was only a click away. There was no statistically significant difference in the use of the notebook (group with drop down menus used the notebook on 60% questions; group with menus always visible used notebook on 55% questions) (Students $t<1$, ns). This suggests that the menu difference affected people's memory for where to go but not for what they found. This dissociation points to different memory subsystems being involved in remembering what to do and remembering verbal information such as prices.

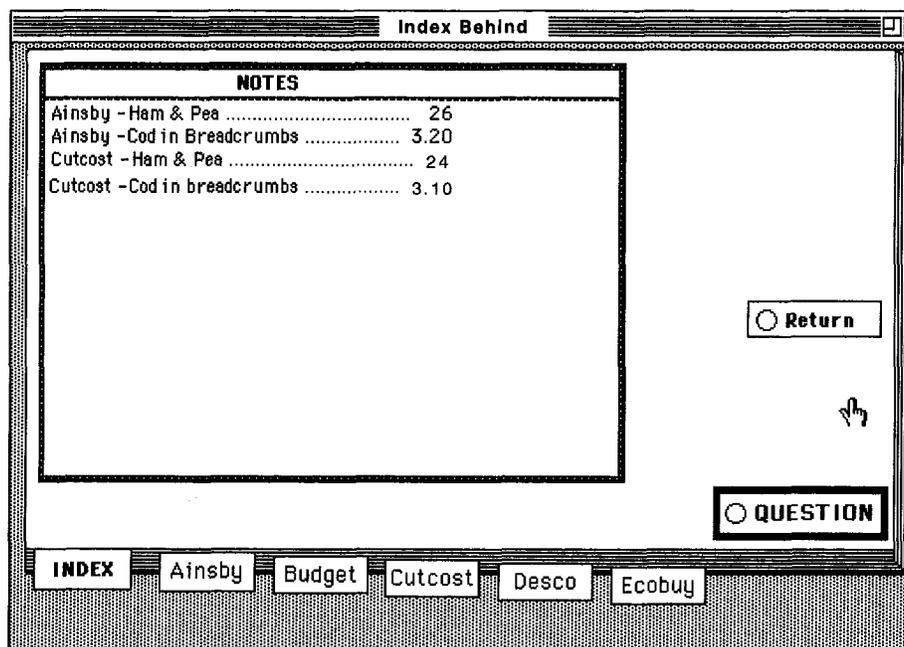
Index Use

People's choice of the method for accessing price lists (menu, index, planner) varied with question difficulty but the increased use of memory support cannot be attributed to differences in the way readers' chose to access price lists because the two groups did not differ in the overall frequency with which they selected each of the options. As in experiment 1, both groups used menus more often than the index (people with drop down menus used the menu on 42% questions and used the index on 29% questions; people with the menu always visible used the menu on 42% questions and used the index on 27% questions). The greater use of memory support with the drop down menu therefore seems to be caused by the cognitive overheads arising from working with information that has to be summoned to the screen before it can be used, perhaps because summoning the information becomes an extra subgoal in the task and so means an extra plan has to be constructed and this is something extra to be remembered.

People's Experience

The volunteers who took part in these studies were not experienced computer users. Inevitably the question arises as to whether extra clicks would be similarly costly for people who

Figure 3. A typical notebook page for questions about two products in two shops.



were more accustomed to working with a point-and-click interface. Research on memory processes has shown that once a sequence of actions becomes well learned, then the memory overheads for those actions are greatly reduced. However it is not clear that tasks of the kind used in the present experiments, i.e. tasks involving information retrieval and comparison, will necessarily become automated actions. This is because readers will often be making fresh decisions about how to tackle the current problem – e.g. whether to try remembering all of the question or only a part, whether to make notes or compare prices as they are located, whether to access prices via the menu or the index. This rich optionality may result in tasks of this kind seldom being done in an automated way. Furthermore the data suggest that people had specific rather than general memory problems. Experienced computer users may be no better at remembering where to go next than were the volunteers in these studies.

CONCLUSIONS

These findings suggest that interface designers need to provide additional memory support for people working on computers with small screens. The studies also help to explain the success of icon bars, or ribbon displays, at the top of a window/screen which give people immediate clickable access to functions they frequently need. This rapid access saves them using conventional menu or command systems which, because they require more actions, may impair people's memory for other task components. The present data also show that larger screens can have subtle advantages for readers of on-line documents and can reduce the cognitive overheads of working with computer displays. Even small changes in memory load are important because they change the way people work with information.

About the Authors

Patricia Wright is Assistant Director of the MRC Applied Psychology Unit in Cambridge, U.K. Her research explores the

cognitive consequences of information design across domains as diverse as hypertexts and hospital buildings. In particular she is concerned with the impact of design decisions on users' strategic choices about how they will work with the available information.

After graduating in mathematics from Cambridge University, Ann Lickorish gained considerable programming expertise. For the past decade she has worked part-time for the Medical Research Council, collaborating with Patricia Wright on a variety of research projects relating to numeric, verbal and graphic information.

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Figure 4. The three available Drop Down menus (Stores, Section, Shelf) are on the right of the price list.

