Chapter 7

Conclusion

The idea of allowing users to make use of data and actions from an earlier part of their interactions within the context of their current interactions is the basis of many history-based tools that system designers have provided. However, these tools are not an integral part of any user-support tool suite. Furthermore, there is little empirical evidence that such history tools are effective and little information concerning the important characteristics of a history-based, user support tool. Therefore, a natural research question is whether history tools can, and do, enhance and support user interactions?

This question is examined from three different perspectives: design, user behaviour, and human information processing. Our first set of studies, in Chapters 2 and 3, examined history-tool artifacts to identify seven history uses, to assess the degree to which current artifacts support all seven history uses, and to propose requirements and options for enhancing current designs. Our second set of studies, in Chapters 4 and 5, examined real user behaviours for information about command recurrences and history-tool usage. Our final set of studies, in Chapter 6, examined the mental and physical effort associated with issuing a recurrent command and the implications that mental and physical effort have on the design and use of history tools.

Except for the first set of studies, the primary focus is on history tools which support the literal reuse of previous interactions. Other history uses and other ways to reuse activities (e.g., partial reuse) have not been examined in detail. However, based on our studies of reuse, the results are favourable towards the use of history tools for supporting recurrent user interactions.

Contributions

There are four major contributions of this thesis. The first is that our findings, along with Greenberg (1988b)'s, represent an accumulating collection of information about the behavioural, psychological, technological, and user-task factors influencing the design and use of history tools. Our studies represent only one of two formal examinations of history tools and the only ones to have examined the cognitive and behavioural merits and drawbacks of history tools for user support. Our primary findings are as follows:

(1) We uncovered seven potential uses of history (i.e., reuse, inter-referential I/O, error recovery, navigation, reminding, user modelling, and user interface adaptation).

(2) We observed that current history tools do not support all seven history uses and we proposed requirements and options for history tools that integrate all seven history uses.

(3) We observed that *csh* and *tcsh* users make limited and simplistic use of history tools.

(4) We observed that users make repeated references to a small group of commands at certain intervals in their session. We demonstrated that this user behaviour, locality of command recurrences, is a more meaningful characterization of command recurrence behaviour both in terms of accounting for history use and predicting reuse opportunities and reuse candidates.

Locality and working set were examined previously within the context of window references [Henderson & Card, 1986a; Card, Pavel, & Farrell, 1984], but our study of locality replicated these earlier observations for a finer grain of behaviour: issuing command directives to a system. This replication and generality is an integral part of any research, and especially research in HCI. More importantly, our research demonstrated, in a formal way, that locality in user commands is not a randomly occurring behaviour but a behaviour which arises as a direct result of user-computer interactions.

The Greenberg (1988b) study provided the initial observation that users repeat their commands frequently, especially recently-issued commands. Our studies followed up on his study by corroborating his findings and demonstrating that locality is a better characterization of command recurrence. Greenberg (1988b) also provided insights into the performance of different history-prediction techniques that exploit this recency characteristic. We proposed an alternative which takes locality into account.

(5) We used cognitive modelling to generate predictions about the mental and physical effort involved in the task of specifying a recurrent command for a given method and design. Thus, we do not model the task of deciding which method (i.e., history tool or typing) or which history-tool designs to use for command specification. We assumed that the command had been generated and appeared in the user's working memory. We also assumed that users exhibit expert, error-free task performance behaviour. Within the scope of these constraints, we drew three conclusions. First, most of our proposed history tool designs favour less physical effort at the expense of more mental effort while re-typing favours less mental effort at the expense of more physical effort. Second, the increased mental effort associated with using history tools can be alleviated by designing history tools that exploit simpler mental operations (e.g., working memory retrievals and perceptual processing). For example, memory retrieval could be limited to working memory and perceptual processes could be used rather than long-term memory retrievals. Third, despite the penalty associated with switching from typing to history tools, non-expert typists using history tools do expend less overall effort.

The second thesis contribution is the demonstration of the value of using different research methods to study the impact that history tools have on user

interactions. Design is a complex endeavour and requires input from many different perspectives including user task, technology, user behaviour, and human information processing. These various perspectives offer insights into task requirements, technological barriers, behavioural factors, and human information processing constraints. Furthermore, it is important, in any investigation of factors influencing the use of a tool, to involve different granularities of analysis because this can provide macroscopic and microscopic perspectives on important problems and issues which otherwise would not be evident. This thesis is unique in that it examined the prospects of history-based user support from three different perspectives and grains of analysis (i.e., design, user behaviour, and human information processing), demonstrating how the various studies can provide insights into the design problem (i.e., history-based user support tools).

The third thesis contribution relates to our findings regarding locality in command recurrences. These findings provide insights not only for the design of history-based user support tools but also for the design of user interfaces in general. In particular, locality is a basic behavioural phenomenon which user interfaces need to consider and address. Our study revealed poor locality in command recurrences and this observation leads to two interesting conjectures that merit further investigation. One conjecture is that current interfaces do not provide adequate tools and resources so that users can keep unrelated work in separate workspaces. As a result, a user history is a collection of different threads of user activities rather than a single thread of user activity. A second conjecture is that poor locality is an indication of a good user interface design. A good user interface design imposes fewer constraints on users and as a result, users are better able to accomplish their tasks with less trivia because of user interface flexibilities. Also, this means that users are not forced to use the same method to accomplish their tasks; they can use different variations. This variation would be manifested in the form of less locality in user interactions. A study into the cause of poor locality is required before we can conclusively explain the observation of poor locality in user interactions.

The final contribution of this thesis is the contributions made in the area of cognitive modelling. These contributions include:

(1) An estimate for a new Model Human Processor operator (i.e., visual search of a menu whose items are organized in the order in which they were last referenced starting with the most recently referenced menu item),

(2) A demonstration of the ability of MHP/GOMS to model user activities (e.g., visual search of a history menu with a known organization, menu selection, and associative memory retrieval) within a new and different task domain (i.e., history tools), and

(3) Additional corroboration that the new and revised estimates of MHP operators (i.e., menu search and mouse selections) are able to model and predict task performance times to within 80% of mean observed times.

Future Directions

There are four research directions in which to extend the work begun in this dissertation: studies of other aspects of history for reuse, studies of other

behavioural patterns motivating uses of history tools, studies of the cognitive and design issues influencing history-based, user support tools, and enhancements to cognitive modelling.

First, the dissertation examined the literal reuse of previous user interactions. However, there is also the issue of partial reuse of previous user interactions which needs to be examined. This includes how people reuse past interactions, which elements in past interactions are most useful, and the mental and physical effort associated with partial reuse of previous user interactions.

Second, behavioural studies are important for identifying and characterizing behavioural patterns evident in user-computer interactions. As demonstrated in this thesis, such behavioural studies provide important insights into the support that users need in their interactions with the computer. Further research is needed a) to identify and characterize behavioural patterns that influence other uses of history tools like the ones identified in Chapter 2 (e.g., navigation, error recovery), b) to examine the implications that each behavioural pattern has on the design of history tools in a fashion similar to that described in Chapter 5 and in Greenberg (1988b), and c) to study the impact that computing artifacts have on locality (e.g., tasks which have more or less locality than other tasks) so as to shed light on the design of artifacts.

Third, research is needed in the design of history tools. An important conclusion from this dissertation is that current history tools are woefully inadequate in regard to cognitive considerations influencing their use. Research is needed to identify important cognitive issues influencing the use of history tools and to formulate solutions to address these issues. A starting point for this research effort is to extend the design issues and requirements enumerated in Chapter 3 and to explore the design solutions outlined therein.

Finally, psychological model building allows designers to explore their design intuitions, to explore and understand the mental and physical processes and constraints underlying the use of a design, and to predict the efficacy of design proposals. Cognitive modelling shows promise not only in terms of providing a bridge between psychological theories about human behaviour and design proposals for supporting them but also in terms of influencing its own development as a research tool. That is, by using the methodology to explore real design issues, we can identify its limitations. Therefore, we can help drive efforts to broaden the methodology's scope, applicability, and usefulness.