MONITORING AND ANALYSIS OF HYPERMEDIA NAVIGATION

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The use of an interaction monitoring tool in conjunction with commercial spreadsheet and statistical packages is described. The tool was used to monitor and analyse M.Sc. students' use of a hypermedia system with multiple navigation structures to study course content. The final product of the analysis is a description of the navigation routes and methods used by individual students to acquire information from the courseware. Post hoc, students were clearly separable into those who performed relatively more, and those who performed relatively less, actions per minute. These two groups were also different in terms of their use of the available navigation structures and the content they chose to visit. The role of high level monitoring tools and associated analysis packages in evaluating hypermedia material, and in answering questions about human learning, is discussed.

1. INTRODUCTION

This paper describes the use of a specialist monitoring tool, in conjunction with commercial general purpose analysis packages, to investigate students' behaviour using Hypermedia learning materials composed of multiple navigation structures. There are two major aims of the research. The first is to answer substantive questions about how students use the courseware in terms of routes and methods of navigation, and topics explored. The second is to illustrate the systematic use of the monitoring and analysis tools, from collection of the raw data in the form of time-stamped protocols, through to the production of results in a form which can shed light on substantive theoretical and pragmatic issues.

Hypermedia systems have the potential of allowing users to follow their own paths through a body of information; but all too easily they can create confusion, if navigation proves too difficult.

Of particular importance for ease of navigation may be the designer's conceptual model of the system structure, of the organization of its nodes and links, and the cues which help a user to form a coherent model. Wright and Lickorish (1989) categorize navigation structures as linear sequences; modules; matrices; hierarchies; & networks. Some structures can be portrayed via a map (Nicol, 1988). Hammond and Allinson (1989) view maps and indexes as access and guidance tools, and show that learners' use of a system is substantially influenced by the tools provided. Monk, Walsh and Dix (1988) describe the use of a hierarchical map, and conclude "It would seem that providing a map ... is of crucial importance".

Monitoring learners' interaction with hypermedia has the potential to provide information of importance to teacher-authors about the content explored in terms of the cards visited, text fields activated and simulations performed. Monitoring can also provide information on the modes of navigation used by learners to control their pathway through an information structure. Such information is important for hypermedia designers because it can give a systematic account of the navigation methods students actually use. It is important for authors because it can provide a principled way for guiding decisions about the presentation and linking of topics. It is important for cognitive scientists because it highlights the processes involved in student initiated learning.

1.1. An Example of Hypermedia Courseware

'HyperCard Basic Concepts' (Macleod, 1989b), is an example of hypermedia courseware presenting the concepts underlying HyperCard™. It employs what may be termed *'conducive redundancy'*: the co-existence of multiple navigation structures, presented to the user in a manner which seeks to enable the formation of complementary conceptual models. The structures are designed to allow the user to explore the system in different ways at different stages of learning, to have multiple means of recovering from getting lost, and to have information available about unvisited nodes.

Some of these structures are represented in the map shown in Figure 1. In total, they comprise the following.

A. A *linear sequence*, intended to allow the student to step gently through the major concepts, using standard

arrow screen-buttons, or keyboard arrows. The order of topics in the sequence is given in the topic codes listed in Fig. 1. Cards which exemplify or make subordinate points are only accessible via other links and are deliberately excluded from the linear sequence, they comprise the advance field material and some advanced button material.

B. A *network* of hypermedia links for exploring individual concepts and their connections. The network is designed to provide easy access to related ideas at all points. Network "jump" opportunities are signalled by enclosing the destination name in a box. It has been found necessary to *qualify some of the jump links* with a dialog box outlining the knowledge needed to understand what lies at the end of the link.

C. A graphical *'active MAP'* (or browser) is accessible from any location. This provides a spatial representation of the nodes and their links, a current position indicator, and an immediate means of going to any card (point and click). The map emphasizes a *hierarchical structure* within the network, by highlighting the relevant links.

D. Sub-sequences or topic *modules*. Strongly related adjacent cards are indicated on the MAP by overlapping their icons, and on the cards themselves by signal arrows pointing forward and/or back, within the topic module.

E. Notes and simulation *loops*. Certain words are marked *, signalling that a field with additional text will appear when the user clicks on them. A user may re-hide the note field by clicking it, or by re-clicking the * word (toggle). All still visible notes are hidden by the system when a user leaves a card. Simulations which loop back to their starting point can also be activated by clicking within a card.

1.2. Investigation of Navigation and Content

Hypermedia encourages active learning, but as yet relatively little is known about the global characteristics of its use. The first goal of this study was to obtain a descriptive overview of interaction.

A more detailed analysis of navigation explored the different paths learners took, by comparing the number of actions in each of the navigation structure categories listed above. The means used for navigation were determined by comparing counts of the different kinds of user action in terms of mouse clicks, hypercard menus and hypercard command keypresses. Content was investigated by examining the number of cards visited and time spent per card in each of the major courseware topic areas shown in Fig. 1. Monitoring and analysis was at the level of individual students. This enabled identification of generalizations across students and of individual peculiarities.
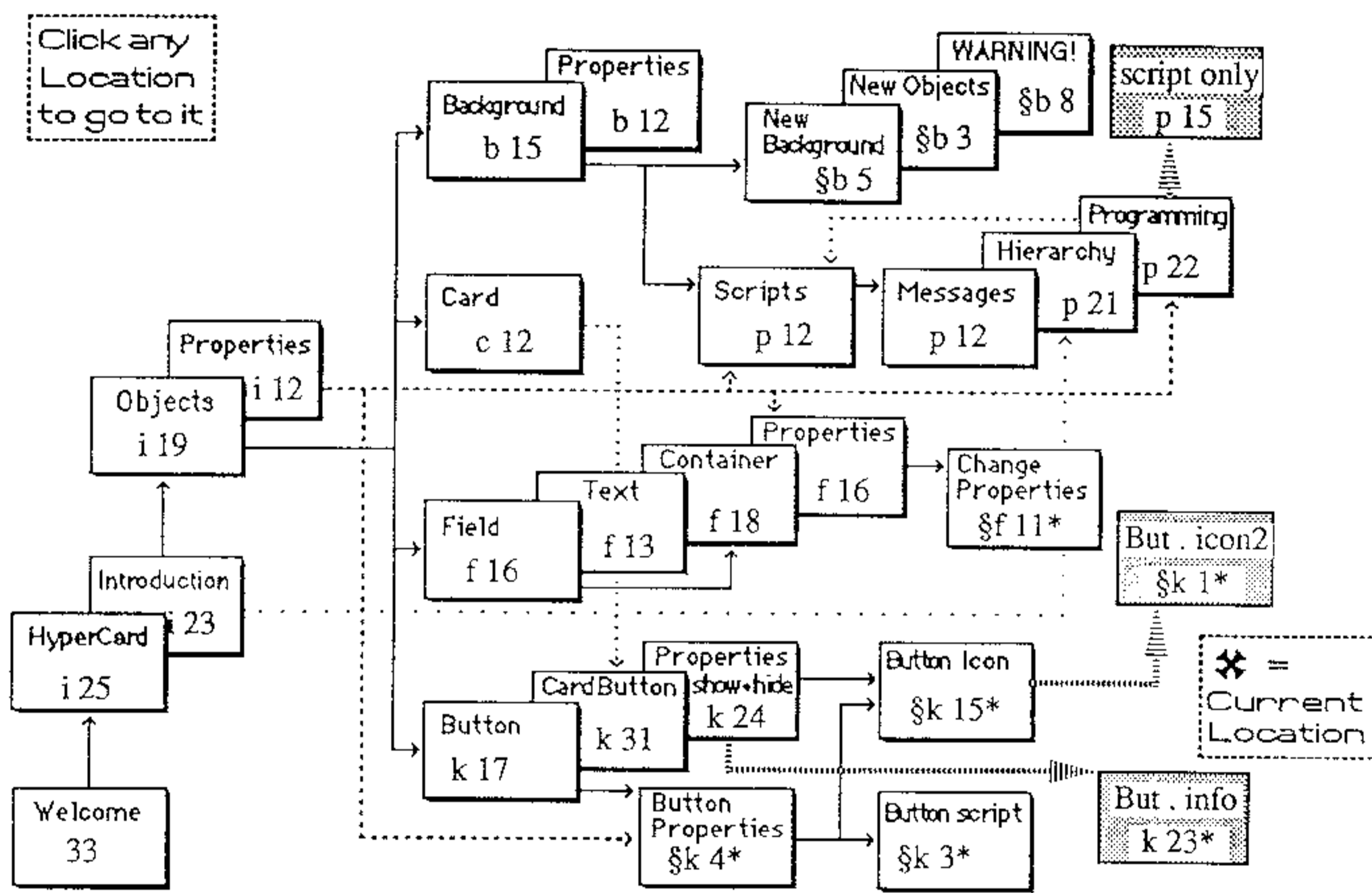

Figure 1. Cards in 'HyperCard Basic Concepts. White background objects and names on them comprise the MAP, as seen by students. In addition, the following items are superimposed and were not seen by students: (a) grey background cards, reachable as shown by striped arrows; (b) topic area code and total number of visists from all students combined, shown in bold beneath the card name. Topic code in linear sequence order: i=intro; c=card; f=field1, intro; b= background1, intro; k=button1 (key), intro; p=script; §b=background2, adv; §k=buttpon2, adv; §6f=field2, adv.

2. THE MONITOR & ANALYSIS TOOLS

To be useful in answering substantive questions, a monitoring tool has to produce output in a form which is easy to analyse. This is often not the case. The output may require new software to be written for each investigation, (Bull & Kornbrot, 1985; Kornbrot, 1990), or may be very low level (Maguire & Sweeney, 1989). Automonitor output can be easily entered into standard spreadsheets for coding and simple statistical analyses, and thence transferred to statistical packages for more complex analyses.

2.1. The Monitoring Tool: AutoMonitor

AutoMonitor (Macleod, 1989a) is a software device which can capture a time-stamped record of interaction between a user and a HyperCard stack. It is unobtrusive, both in its physical presence, and its effects upon interaction, and is simple to use. AutoMonitor records interaction at the level of user actions upon discrete interface objects, such as buttons, fields and menu items. This avoids the common problem of being overwhelmed by information at the lower pixel and mouse co-ordinate level. The output of the inter-action record is in text format. All objects are described by their object type and their name as given by the courseware author. Macleod (1990) describes substantial refinements made to AutoMonitor since Macleod (1989a).

An auxiliary tool, StackMonitor, provides a facility for listing the names of every background, card, field and button in a stack. This can facilitate both the tailoring of object names within a stack, and the subsequent interpretation of actions upon those objects. The object list may be used for inspecting existing object names; checking for missing or duplicated names; and for the creation of an index of stack objects

The AutoMonitor record enables identification of several classes of event which are important for the evaluation of hypermedia systems.
• *Navigation or browsing* through the system.
AutoMonitor records a trace of cards and backgrounds opened and closed, timed to 1/60th second.
• *Display* of pop-up text material ("loops").
The timing of presentation and hiding of fields can be derived from the record.
• *Actions chosen* by users in order to navigate and browse. In HyperCard, these actions may be mouse clicks on buttons and fields, command / keypress combinations, menu choices, or keypresses on the arrow keys, so AutoMonitor records all these individual user actions timed to 1/60th sec.

2.2. Analysis of Automonitor Output

The text form of the output identifies objects by their author-given name. Hence, even non-automated visual inspection enables identification of which navigation structures have been used at which times. In 'Basic Concepts', for example, linear navigation employs the 'Next' and 'Prev' buttons (or arrow keys); use of the map employs the 'MAP' button; and exploration of the network of links employs embedded text buttons.

The spreadsheet EXCEL™ was used for more detailed analyses. Raw data from each student together with the complete objects list from 'StackMonitor' was read into EXCEL. Encoding schemes for grouping together like objects were devised, and implemented using EXCEL's powerful logical functions. For example all buttons with names starting 'go_' were given the navigation action code 8 which corresponds to "jump" in Figure 2. Buttons which initiated jumps but had other names were also given this code. Similarly, each card name was assigned a topic area code. Two versions of the coded data were made for each student: one sorted by card and then by time; the other by user action and then time. Two group sheets containing data from all 8 students were created: one for actions and one for cards and topics. These group coded sheets were transferred to the statistical analysis package STATVIEW 512™ to obtain the statistics which are reported in the results section.

Once the templates have been created, the mechanics of the process of getting the results of a single student/session into the file for STATVIEW analysis takes about 20 minutes. The EXCEL coding frames are available from the authors in a form which could be used as a template for similar investigations of other HyperCard stacks.

3. METHOD

The data for the analysis were captured by monitoring the use of hypermedia courseware in a normal educational environment. Subjects were 4 male, and 4 female students, aged between 25 and 49, in the second year HCI option of a part-time Computer Science MSc 'conversion course'. All had been introduced to HyperCard, and had some experience of beginning to create stacks (programs).

The students were informed that the purpose of the study was to find out about how people use the courseware, 'HyperCard Basic Concepts', when trying seriously to understand and learn about the concepts it presents. They were asked to study the information available in the

arrow button. The use of the *network* "jump" method which takes them via one of a small number of author-prescribed routes indicated by an outline box frame is next in order of frequency of use. There is also substantial backtracking using the "recent" and "previous" arrow buttons. Navigation using the "MAP" is relatively rare. By contrast, the "more" group uses "next", "previous" and "jump" with similar frequency to the "less" group, but makes far greater use of the "MAP" route.

In terms of *loops* which occur during a card visit, "more" and "less" students make about equal use of the toggle switch to examine additional note material indicated by the symbol *. The "less" students do *not* click on the notes to make them go away. They either use the toggle by re-clicking on the starred item or leave the item to be closed automatically by the system when they leave the card. The "more" students also spend more time "playing" with the demonstration simulations.

Finally, the "more" students perform more actions on general hypercard objects, as is also shown by their use of the hypercard menu and command key presses in addition to mouse clicking (shown as menu+ in Figure 2).

4.2. Topics

The total number of visits to each card summed across all students, together with the associated topic code, is shown in Figure 1, superimposed on the relevant cards. Cards which accessed simulations have number of visits marked with a *. Only three students visited all the topics and all advanced material was omitted by at least 2 students.

Figure 3 shows the mean time students spent on each major topic content area. The "less" group averaged 18.9 out of 22.6 minutes on content cards while the "more" group averaged 18.7 out of 21.2 minutes on content cards. What is salient is that the "less" group spent more time on the introductory material, while the "more" group spent
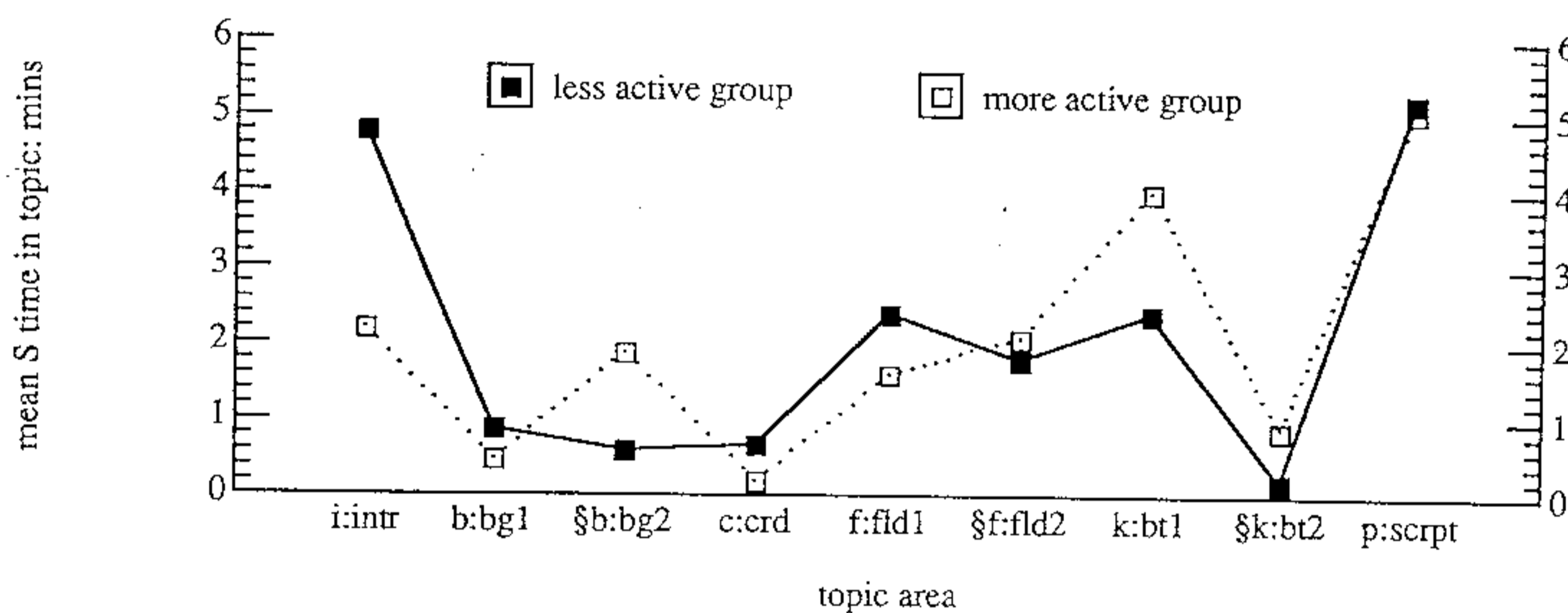

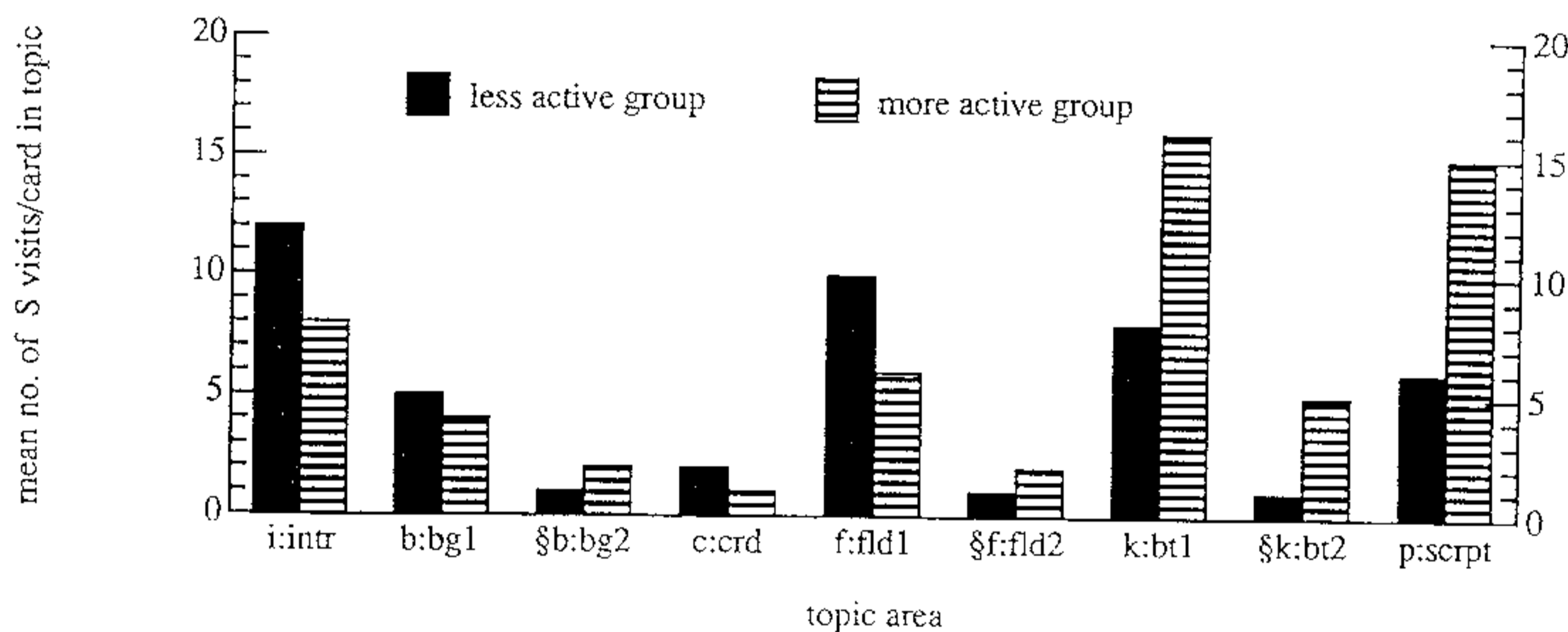Figure 3. Mean total time in minutes spent in topic area by "less" and "more" active students

Figure 4. Mean number of card visits in a topic area by "less" and "more" active students

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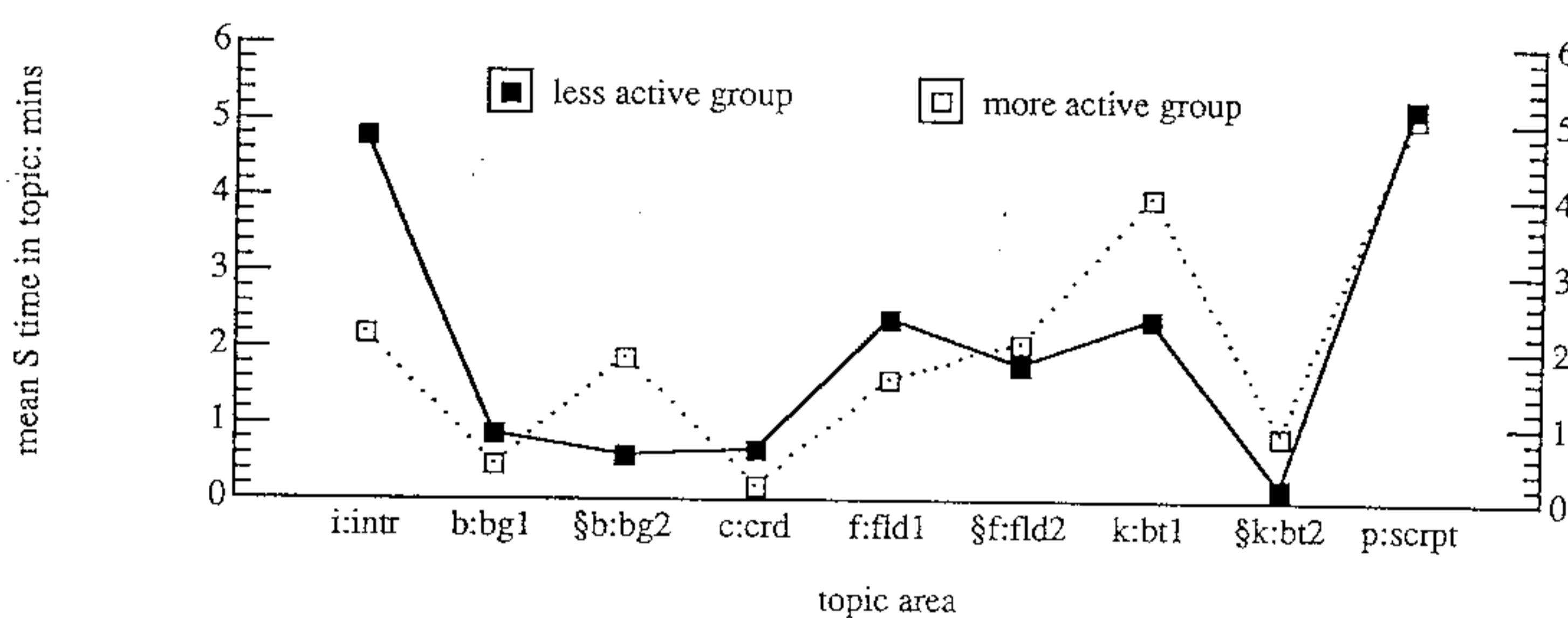

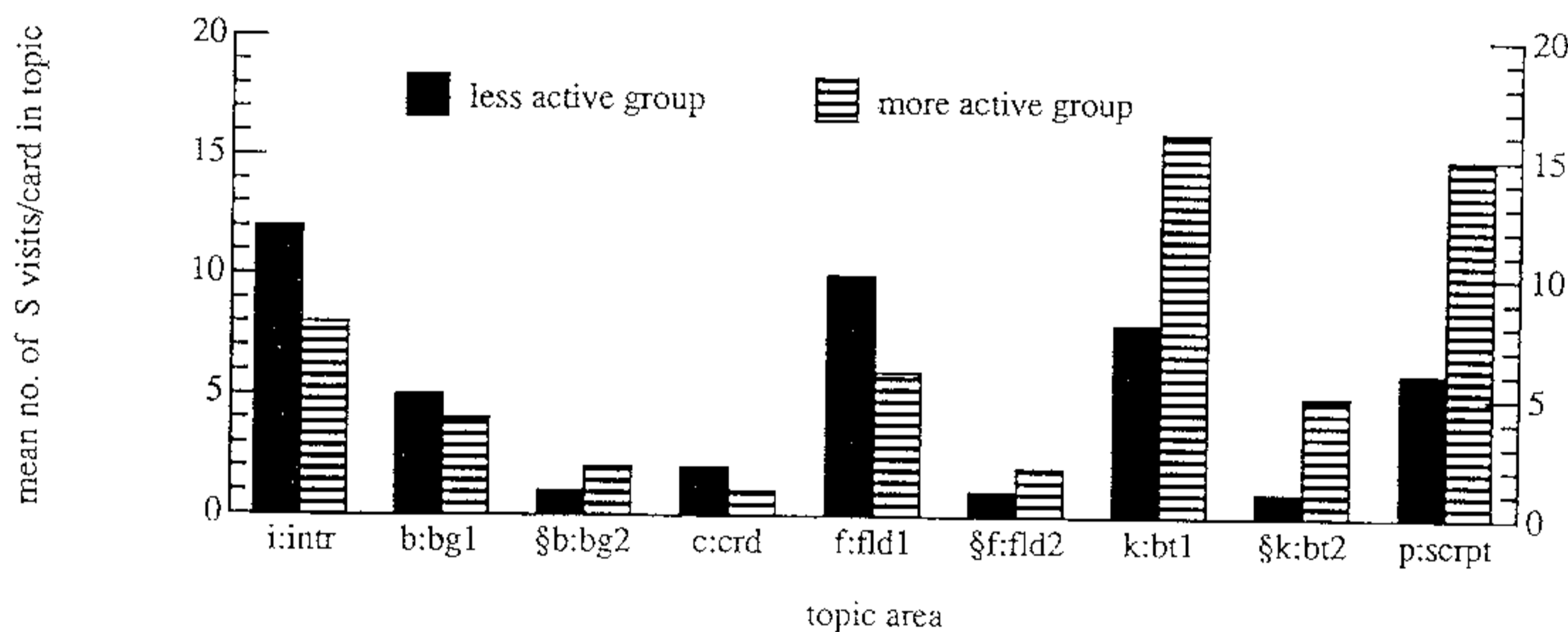Figure 3. Mean total time in minutes spent in topic area by "less" and "more" active students

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more time on the buttons and the more advanced material. Neither group spent much time on cards and backgrounds.

Figure 4 shows the average number of visits to cards in each topic area. The pattern is obviously similar to that in Figure 3 for time, but there are some important differences. In particular the "less" students make *more* visits to the more elementary topics: introduction , background1 and field1. The "more" students pay more visits as well as spending more time on buttons and background2. However they make more visits to the script topic than "less" students, although total time on this topic is identical.

5. DISCUSSION

The use of AutoMonitor in conjunction with EXCEL and STATVIEW enabled us to produce a clear picture of how students used the 'Basic Concepts' courseware in a real learning task, where they might be motivated to acquire the knowledge for their own purposes, as well as to satisfy course requirements.

Interesting features emerge from the analyses of students' interactions. In terms of navigation, all students used all the available navigation structures. However, "more" and "less" active students had discernibly different patterns of behaviour. In particular, the "more" active students did more navigating via the MAP; spent more time on the interactive simulations; and were more likely to use the generic HyperCard menus and command keys.

In terms of topics visited, all students explored at least some of the less advanced material. There was little difference between students in number of card visits or number of visits per card. Interestingly, all students made multiple visits to more than half the cards, seeming to prefer 'little and often' to a single extended visit. This may may be a general feature of the way people study complex information which merits further investigation.

These substantive findings would have been difficult, if not impossible, to acquire without the use of an object level monitor. Co-ordinate based automatic records do not produce results in interpretable cognitive units. On the other hand, video-recordings do not provide detailed counts and timing of precisely specified events.

The present study serves to illustrate the potential of object based monitoring in general, and AutoMonitor in particular. The logical capabilities of spreadsheets such as EXCEL make it possible to specify any event for analysis, even after the data has been collected, not just those investigated here. For example, one might wish to examine particular sequences of card visits where a student looks successively at all cards which mention 'properties'.

Using AutoMonitor to analyse a considerable body of data with particular substantive questions in mind has led to several changes which materially improved the power, functionality and usability of AutoMonitor. Progress, both in understanding the use of hypermedia for learning, and in the development of better monitoring tools, is likely to result from close collaboration between workers in the role of tool developer, author and HCI psychologist.

In summary, this work serves to show how an object-level monitoring tool can be used to discover psychologically important features of how people use hypermedia for learning. It also relates the use of hypermedia to the available navigation structures.

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