The Effects of Menu Parallelism on Visual Search and Selection

Philip Quinn **Andy Cockburn**

Department Computer Science and Software Engineering
University of Canterbury,
Christchurch, New Zealand
Email: {ppq10, andy}@cosc.canterbury.ac.nz

Abstract

Menus and toolbars are the primary controls for issuing commands in modern interfaces. As software systems continue to support increasingly large command sets, the user's task of locating the desired command control is progressively time consuming. Many factors influence a user's ability to visually search for and select a target in a set of menus or toolbars, one of which is the degree of parallelism in the display arrangement. A fully parallel layout will show all commands at once, allowing the user to visually scan all items without needing to manipulate the interface, but there is a risk that this will harm performance due to excessive visual clutter. At the other extreme, a fully serial display minimises visual clutter by displaying only one item at a time, but separate interface manipulations are necessary to display each item. This paper examines the effects of increasing the number of items displayed to users in menus through parallelism—displaying multiple menus simultaneously, spanning both horizontally and vertically—and compares it to traditional menus and pure serial display menus. We found that moving from serial to a partially parallel (traditional) menu significantly improved user performance, but moving from a partially parallel to a fully parallel menu design had more ambiguous results. The results have direct design implications for the layout of command interfaces.

Keywords: Menu selection, visual search process, display design, information density.

1 Introduction

As menus and toolbars become the ubiquitous controls of modern application interfaces, there is a growing challenge for designers to effectively display command items in a way that allows users to efficiently search and select them. The characteristics of a user's visual search patterns for searching traditional menus (Aaltonen, Hyrskykari & Räihä 1998) as well as how users identify targets amongst distractors (Rosenholtz, Li, Mansfield & Jin 2005, Treisman & Gelade 1980) is well known. However, research leans away from understanding the axioms of visual interaction in menus to focus on general evaluations of novel menu designs. Understanding these foundational human capabilities within the context of user interface design is important in informing designers about the performance implications of new design variants. Microsoft's recent redesign of the command control, replacing menus with the context sensitive 'Ribbon' toolbar, is a good example of where such underlying research could be deployed.

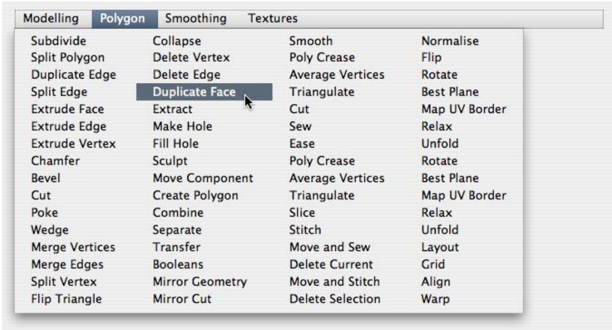

Figure 1: Four menus displayed in parallel.

Traditional menus are limited in their display of the menu hierarchy, restricting the user to interact with one menu branch at a time. Depending on the user's experience with the menu structure, this limitation may impair the performance of novice users when attempting to locate an unknown menu item to perform a desired command. Revealing all menu items would present the user with rapid access to search every menu item. For experienced users, memory tasks are involved to remember the spatial location of menu items—both the menu that contains the item, and the location within that menu. A parallel menu display would require memory of only one spatial location in a 'grid' of menu items to be learned, potentially making visual memory more efficient and improving subsequent recall. In both cases, parallel menus present the opportunity for faster cursor access and easier menu activation.

We present *parallel menus* as a menu display technique, which maximises the use of screen space to display multiple menus simultaneously. Figure 1 shows a menu using this technique to display all four of its menus simultaneously, this is in contrast to a traditional menu, shown in Figure 2, displaying only one menu (but still showing multiple items vertically, thus classed as *partially parallel*). A parallel type of menu provides immediate visual and pointer access to all menu items in the menu structure, eliminating the additional steps of opening each menu individually to scan its contents in a traditional (partially parallel) menu.

We evaluated, through a quantitative user study, the performance of three menu display styles—serial, partially parallel, and (fully) parallel. Serial menus (Figure 3) only display one menu item at a time to the user; partially parallel menus (Figure 2) allow the user to view a branch of menu items simultaneously; parallel menus (Figure 1) allow the user to view all top-level branches of all menu items simultaneously. The study also compares these menu designs in two layout configurations of menu items (4 top-level menus with 16 items each, and 8 menus with 8 items each). In our evaluation, we found significant performance improvement between serial and both other menu types in all conditions. Between partially parallel and fully parallel menus, no significant difference in performance time was found, contrary to the suggestions of prior research.

2 Related Work

Our paper focuses on three fields of prior research: visual search, mouse-pointing and selection, and menu design.

2.1 Visual search

Treisman and Gelade's feature integration theory (1980) studies how people can pre-attentively analyse a set of objects. This is dependent upon the distinctions between each object in several dimensions. The higher the distinction between the target and its distractors in these perceptual primitives—such as colour, shape, and orientation—the better participants could pre-attentively examine a set of objects and then proceed to rapidly identify a target (suggesting a parallel examination of items). The reverse also held where participants reverted to a serial search of individual items when the target and the distractors were visually 'close' in those dimensions. In most pull-down menus, items are only distinct in their textural contents (altering the shape of each character and the overall textural bounds) but identical in their colour and orientation. Without more distinct visual identifiers, Treisman and Gelade's findings suggest that increasing the number of menu items displayed simultaneously would reduce the possibility of a pre-attentive examination of items and force users to degrade to a serial visual search pattern of all items.

Visual density is another changing factor when transitioning from a serial display to a parallel display, more-so as the number of dimensions that targets are displayed in increases. In examining how users visually search two-dimensional visual hierarchies, Hornof (2001) reviewed the work of Thacker (1986) and Treisman (1982), supporting Galitz's (1996) recommendation that no more than 30% of a screen should be used for information display (and the remaining 70% should remain blank). However, further studies (Burns 2000, Staggers 1993) examining the effects of changing the density of visual information displays in specific environments indicate that this recommendation is highly context-dependent in where it can be applied. However, unlike information displays (like those used in the environments studied by Burns (2000) and Staggers (1993)), menus are generic regardless of context—menus are facilitators to the manipulation of information, their display is always that of a temporary assistive device. Therefore, if menus are context independent, Galitz's reccomendation may hold for their display and suggest a slower visual search and selection for parallel menus.

Aaltonen et al. (1998) used eye movement data to examine the patterns employed by users to search menus. The results of their study shows a non-random vertical

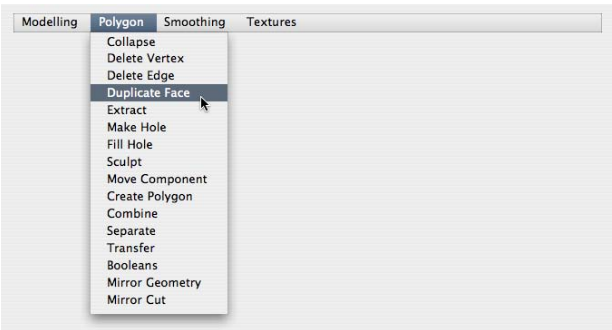

Figure 2: A single menu (from Figure 1) open using a traditional, or partially parallel, method.

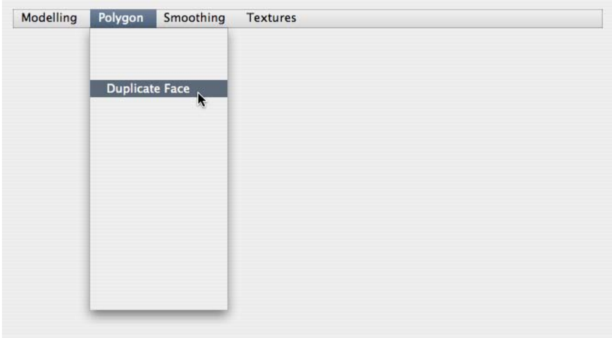

Figure 3: A menu (from Figure 1) displayed using a serial technique.

search in the serial scan paths of users. Participants were found to scan menu items in 'sweeps'—analysing groups of menu items with no visual fixations, significantly reducing the visual search time. However, only one axis (vertical) for visual search was examined. As the number of dimensions of item display increases, so does the complexity of the visual search strategies that must be employed by users. Everett & Byrne (2004) found that as the spacing between icons in a two-dimensional grid changed, so did participant's visual search strategy, much to the detriment of their response times. However, Everett and Byrne were not able to determine why a spacing change produced a change in search strategy.

2.2 Mouse-pointing and selection

Fitts' Law (1954) is the seminal work on human motor action for target acquisition, describing the movement time taken to acquire, or point to a target. Small and distant targets demand more motor input than large and near ones. For traditional menus, two selection tasks must be made—one to activate the menu, and another to select the target. Moving from partially parallel to parallel menus, the number of selections that need to be made remains constant, but the activation area for one changes. In parallel menus, because activating one menu causes the effective activation of all menus, the target for opening any one menu becomes the combined target of all top-level menu activation areas. Modelled using Fitts' Law, this increased target size would result in a reduced movement time to acquire the target and activate a menu. Parallel menus also eliminate the need to switch between menus if the item being searched for does not appear in one—completely eliminating the selection of the next menu (and all cursor movement associated with it).

An issue when increasing the visual density into two dimensions is the increase in visual distractors. Hornof (2001) discovered that selection times are slower when there are distractors present in two-dimensions around the target. Participants made slower and more accurate cursor movements to ensure they made correct selections as the danger of selecting a distractor in error appeared higher. A menu item located in the middle of a parallel menu display would fit this description, and Hornof's findings suggest a slower selection time for these menu items. Hornof's research also revealed that labelling groups of items within the two-dimensional matrix of items significantly improved selection times.

2.3 Menu design

There is a substantial amount of research on alternative menu display techniques that alter the visual arrangement and/or density of menu items (Harrison & Vicente 1996, Bederson 2000, Gutwin & Cockburn 2006, Sears & Shneiderman 1994, Kurtenbach, Fitzmaurice, Owen & Baudel 1999, Bier, Stone, Pier, Buxton & DeRose 1993, Kurtenbach & Buxton 1994). However, there is little research that focuses on the efficiency impact of the visual arrangement of items in these techniques, rather than the broad evaluations of the designs.

Space filling thumbnails (Cockburn, Gutwin & Alexander 2006) (SFT) were demonstrated to be significantly faster for locating pages in a document than scrolling through a serial display of pages. A similar technique, ListMaps (Gutwin & Cockburn 2006), using a two-dimensional matrix of items, was demonstrated to be faster for item selection than a serial listbox of items. However, these interface examples are not true tests of serial versus parallel display techniques. Both SFT and ListMaps feature a scrolling aspect in their serial displays that is not present in the equivalent parallel display. Although this is a necessity of the serial displays, it introduces additional cognitive tasks for users to locate a target in the serial display. The added cognitive load of scrolling tasks means that we cannot immediately draw the same conclusions for non-scrolling serial lists, or alternative arrangements of such lists.

The Hotbox (Kurtenbach et al. 1999) is an interesting display of menus; combining a display of top-level menus in rows, with the display of menu contents in a partially parallel form. The Hotbox itself was designed specifically to accommodate the enormous number of menus available in AliasWavefront's Maya application. No formal evaluation of the interface was conducted, but selected unsolicited comments from users were positive about the ease of access to menus, indicating a subjective preference for rapid access to large sets of menus simultaneously. Comments were ambiguous as to how the cursor-localised nature of the Hotbox influenced these opinions.

Radial pie menus (Callahan, Hopkins, Weiser & Shneiderman 1988) and marking menus (Kurtenbach & Buxton 1994) present another arrangement of menu items, moving away from the display of items on a single axis, utilising the space in all directions around the cursor. Callahan et al. (1988) found selections from pie menus to be significantly faster than linear menus. However, pie menus have significant advantage for pointing time tasks and no distinction between visual search time and pointing time was made. The gestural nature of both pie and marking menus also give them advantages in learnability and speed of command issue.

This prior work shows a large volume of research and evaluation of visual search, pointing time, and an assortment of menu designs. However, it also shows a lack of dedicated research into the core combination of these three aspects to show the interaction of these three components in user performance. There is a strong need for further research to evaluate the effects of a menu's visual arrangement on a user's visual search and selection time.

3 Experiment

We evaluated three different menu display techniques: serial, partially parallel, and (fully) parallel. Using two different menu configurations (both using the same number of items). The evaluation used a realistic Zipfian distribution of selections (Zipf 1949), with some items occuring much more frequently than others.

3.1 Menu Designs

Three menu designs were implemented, and evaluated:

Serial The serial menu was designed to allow the user to view only one item at a time, forcing a serial visual search of items. This was implemented by hiding the items of a traditional menu and only revealing their text when the mouse cursor was positioned over them (Figure 3). The size and shape of the menu was equivalent to a traditional menu and borders of the menu were visible.

Partial The partially parallel menu emulates a traditional menu in that a set of items was visible at once (Figure 2).

Parallel The parallel menu revealed all menus simultaneously. That is, regardless of which top-level menu was selected, the items for all top-level menus were posted (Figure 1). The menus were posted as if they had been in a partially parallel menu but arranged such that there was no overlapping of menus. No visual separators between the columns or rows of menu items were used.

Figure 4: A screenshot of the experiment, prompting the user to select the item 'Thailand' and the user having activated 'Menu One'.

Top level menus had the generic names 'Menu One' . . . 'Menu n'. There was no distinct organisation of items within or between menus in order to focus the experiment on the visual search of non-predictable items.

A different set of menu items was used for each condition (constant across participants) and pre-defined from random selections of ISO 3166-1 country names. It has been well established that the frequency of menu selections in realistic application usage follows a Zipfian (power-law) distribution (Findlater & McGrenere 2004, Greenberg & Witten 1993, Hanson, Kraut & Farber 1984). To emulate a realistic selection of menu items, a distribution of selections was used, as detailed in Table 1. Selection indexes were constant for each menu configuration across menu types to avoid a menu-type bias due to location differences in menu selections. Selections were different between menu configurations to prevent a bias towards one configuration due to the differing menu lengths and arrangement of items with regard to their corresponding selections, and to avoid learning effects from participants.

Menus were activated by a single click on the menu title. Users were not required to hold the mouse button down while inside of a menu, selecting items with a subsequent click on them.

3.2 Participants and apparatus

Twelve unpaid students from the University of Canterbury (all male, Computer Science students) were recruited for the experiment. All were frequent users of mouse-based systems, all with experience using traditional pull-down menus (represented as the partially parallel menus in this paper). All participants had either normal, or corrected to normal vision.

The experiment was performed on an Apple PowerBook G4 1.5GHz running a custom Cocoa application. The display used was a 19″ Compaq 9500 set to 1600×1200 resolution at a refresh rate of 75Hz. A Microsoft optical mouse was used as the pointing device.

Menu Configuration	
4×16	8×8
9	5
29	25
9	5
13	9
15	11
10	6
9	5
22	18
56	52
22	8
12	33
9	5
37	18
9	5
15	11

Table 1: Zipfian distribution for menu selection frequencies. Numbers are the index of the menu item in the set of all menu items. Zipfian R^2 (4×16) = 0.98; Zipfian R^2 (8×8) = 0.96

3.3 Procedure

Before each menu type, participants were given a brief description of the operation of the menu and a screenshot showing a sample menu (similar to Figures 1, 2, and 3). This was to ensure that users were not surprised by the appearance or operation of the menu when first interacting with it. The menus were felt to be simple enough to forgo a practice period. Participants were given the chance to pause between menu type conditions; however, no pause was explicitly given between menu configurations. A textural notice that the menu configuration had changed was shown after the change in configuration occurred. Users could pause with no effect on timing data between each selection, but this was not made explicit to them.

Users were prompted to select a menu item as shown in Figure 4, which remained visible until the item was chosen. No further information was given about the location of menu items, except that they were contained in one of the menus presented.

3.4 Design

The study used a 3×2 within-participants factorial design. The factors were—menu type: serial, partial, and parallel; menu configuration: 4×16 (four top-level menus, each with sixteen items), and 8×8 (a total of 64 menu items in each configuration). Menu type was counterbalanced with a Latin square. Menu configuration was always completed in the presented order (learning effects across configuration are of no interest to the study, so they require no experimental control; potential interactions between menu type and configuration, however, are of interest). Within each condition, participants carried out 15 selection trials. All selections in the experiment took a mean of 11 minutes to complete for each participant.

The system also collected data on the items the user hovered over with the mouse cursor and the pattern of menus opened. Participants filled out a brief questionnaire about their preferences at the end of the experiment.

For 3 menu types, 2 menu configurations, 15 selections per condition, and 12 participants, a total of 1080 selections were recorded.

3.5 Results

A 3×2 analysis of variance (ANOVA) was conducted on selection times and a subsequent post-hoc Tukey Test was performed. A separate ANOVA and Tukey test was conduced on the errors.

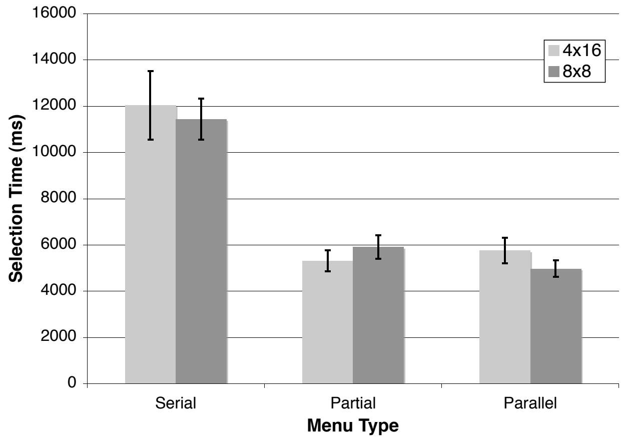

Figure 5: The mean selection times (+/- SE) for each condition.

3.5.1 Selection Times

Selection times were defined as the time taken from opening the first menu after being prompted with the target, to the time the correct selection was made. If errors occurred, timing continued until the correct selection was made.

We found a main effect across menu type ($F_{2,22} = 54.25, p < 0.0001$), where serial menus resulted in the slowest selections (11738.58ms, $SD = 4153.27$) against both partially parallel (5611.94ms, $SD = 1659.58$) and fully parallel (5366.82, $SD = 1623.11$) designs. On further analysis in the Tukey test there was no significant difference found between any pairs of parallel and partial menus. However, any partial or parallel menu configuration paired with a serial menu had a significant difference ($p < 0.01$ for all).

Figure 5 shows the mean selection time of each menu configuration grouped by type. As expected, the serial menu design performed worse than partial or parallel menus. The graph shows an interesting difference between the 4×16 and 8×8 configurations in partial and parallel menu systems, however, this is not significant ($p = 0.579$).

3.5.2 Errors

Errors were recorded, but did not interrupt the selection task. Figure 6 show the percentage of errors in each condition.

There was a main effect between menu types ($F_{2,22} = 6.554, p < 0.01$) with most errors occurring in the serial menu (7.43%, $SD = 0.07$) rather than the parallel (0.78%, $SD = 0.02$) or the partially parallel (3.68%, $SD = 0.08$). Further analysis in the Tukey Test only revealed significant differences between the serial 8×8 condition and the parallel 8×8 ($p < 0.05$) and parallel 4×16 ($p < 0.01$) conditions. No significant difference was found between the partial and parallel menu types ($p = 0.150$).

3.6 Participant Feedback

After completing the experiment, participants were asked to complete a questionnaire independently ranking each menu type on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), as well as pick the menu they preferred using and the one they felt they performed best with.

All but two participants ranked the serial menu type with a '1', indicating a strong dislike for the menu ($mean = 1.25$, $SE = 0.18$); followed by the partially parallel menu ($mean = 3.5$, $SE = 0.29$), and finally the parallel menu type ($mean = 3.25$, $SE = 0.35$). Asked which menu they preferred, 58.3% of participants prefered the partially parallel menu (the remaining 41.7% prefering the

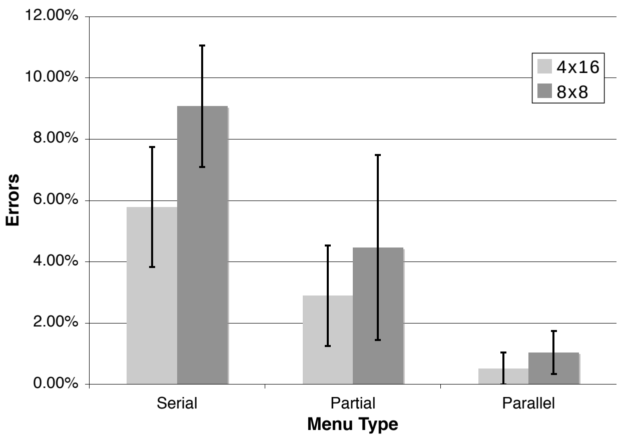

Figure 6: The number of errors (as a percentage of the total number of selections) for each condition (+/- SE).

fully parallel menu). Asked which menu they felt they performed fastest with, 58.3% felt they were fastest with the fully parallel menu (the remaining 41.7% prefering the partially parallel menu).

When asked for comments on the experiment, the majority of participants expressed extreme discomfort with the serial menu, unanimously complaining of eye strain and fatigue.

4 Discussion

The discovery of no significant difference between partial and parallel menu types is interesting considering the suggestions in the results of prior research between one and two-dimensional targets and the effect of distractors (Treisman & Gelade 1980, Galitz 1996). Prior work indicated that such an arrangement of menu items would have a negative impact on visual search and selection times (Hornof 2001, Everett & Byrne 2004), but none was found. The following sections discuss each menu type in turn.

4.1 Serial Menus

Serial menus were the only menu type to perform significantly different than both partial and parallel menus. This is believed to be due to the constraints imposed upon participants ability to visually scan for menu items. Participants were unable to perform the ‘sweeping’ inspections described by Aaltonen et al. (1998), having to inspect every item in a frustrating fashion.

Participants were also observed to over-estimate their skills at visual search at fast speeds, often accidentally either skipping over or not correctly identifying the item they were asked to select and continuing to scan the remainder of the menus before starting the search over again. This was supported by analysis of the hover patterns recorded by the experimental application: as a participant’s visual search pattern was described by these hover patterns, they are an accurate measure of how each user visually searched the serial menus.

The high error rate for serial menus also indicates that the forced visual inspection process did not encourage users to be more precise and scrupulous with their selections. Instead, the overriding frustration with the interaction style pushed participant reactions to try and make the selections as rapidly as possible.

4.2 Partial Menus

The transition from serial to partial menus produced a significant effect in both selection times and error rates. This could lead to the conclusion that an increase in the parallelism vertically improves menu visual search and selection, however, this conclusion does not hold when considering the move from partial to parallel menus.

It is theorised that the reasons for the improvement are related to the ability to perform a more ‘normal’ visual scan of items with the removal of the dependency on additional mouse-pointing interactions for each menu item.

4.3 Parallel Menus

Parallel menus were the novel style of menu display being presented. Its performance characteristics were hypothesised to be lower than that of partial menus due to the increase in visual density, the distractions to visual search patterns, but could be offset slightly by the reduced Fitts’ Law tasks.

Significant learning effects are not believed to have occurred due to the limited number of selections made. However, the Zipfian distribution of selections and analysis of the logs reveal learning effects for a few menu items with the highest distributions (this occurs across all menu types). As visual search and selection times were not distinguished in the experiment, it is possible that parallel menus introduced an increased learning experience, but was offset by slower selection times due to users taking a more precise process (as indicated by Hornof (2001), and the indicated lower error rate for parallel menus). However, these conclusions cannot be drawn due to the limited scope of this study.

5 Future Work

Due to the time constraints, only a limited number of menu configurations were evaluated. Future work may consider extending both the number of items displayed (in total) and the configurations of those items across the same menu types. For example, extending the test to menu item lengths of 32 and 128 items in order to try and observe the interactions between menu lengths across menu types. Studies of parallelism expansion in different dimensions (such as horizontal versus vertical expansion) may also reveal interesting results on the differences between visual search patterns in differing dimensions and levels.

Further analysis to determine the alterations in visual search strategies through analysis of the menu item hovering data or eye tracking equipment would is also a possibility for future work to explore the underlying changes that occur when changes to the visual arrangement of information are made.

Another area that could not be explored due to time constrains was the learning effects of each menu type. Future work may consider several blocks of selections in each menu type to observe the interactions between each menu type as users become more familiar with each menu and its contents.

Separating the visual search time from the mouse pointing time (a technique is described by Hornof (2001)) to isolate the specific changes to both visual search and pointing time as the transitions from serial to parallel are made is another avenue to explore the interactions between these two factors in changing menu arrangements.

6 Conclusions

Menus are an integral part of user interfaces, and the styles for displaying and accessing their contents is an ever-evolving part of HCI research. We presented two menu types showing both a decrease in parallelism by reducing the number of items shown at once, and an increase in parallelism by expanding the items shown to multiple menus. The results of our empirical evaluation found no significant difference between the partial and parallel menu types, although a significant difference was found between serial and partial/parallel menus. These results disagree with prior empirical studies theorising and evaluating other systems. We hope that this will stimulate future work into exploring the cause of these results and will be of benefit to future menu designs that wish to employ techniques that increase parallelism or multi-dimensional menus.

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