

Multimodal Menu Interface for Mobile Web Browsing

Xiaochuan Ma
IBM China Research Lab
Shang Di 5th St, HaoHai
Building
Beijing 100085, China
+86-10-62986677
maxc@cn.ibm.com

Paul P. Maglio
IBM Almaden Research
Center
650 Harry Rd.
San Jose, CA 95120, USA
+1-408-927-2857
pmaglio@almaden.ibm.com

Hui Su
IBM China Research Lab
Shang Di 5th St, HaoHai
Building
Beijing 100085, China
+86-10-62986677
suhui@cn.ibm.com

Abstract: This paper presents a menu-based interface intended to support web navigation through multimodal interaction on small displays. As common starting points for web browsing and searching, portals organize links to news, entertainment, and other kinds of content. The problem is that portal navigation is tailored mainly to large displays and point-and-click interaction, but most mobile devices, such as cellphones, have small displays. Moreover, mobile devices provide only a limited means for interaction, such as keypad entry. The question is how to provide convenient portal access for mobile users. Our approach to facilitating portal navigation on small mobile devices relies on transcoding middleware, software running in the network that adapts markup and content to device capabilities. Our middleware tailors portal markup to present visual hierarchical menus, enable keypad-based and spoken input, and allow for spoken audio output. Results from a user study that compared our multimodal menu-based interface with standard portal interfaces on small displays indicate that our interface (1) requires fewer button presses to find information, and (2) is subjectively preferred by users.

Keywords: Multimodal, web browsing, mobile device, user study.

1 Introduction

Despite much optimism a few years ago, web browsing on mobile handheld devices has not yet caught on with the general public (Batista, 2000). There are many possible technical and social reasons for this. One technical reason is the lack of technologies that help people interact with the web on a mobile device with only limited display and intermittent connectivity. For example, many popular web portals provide hundreds of links and summaries on pages designed to fill full-sized screens (e.g., 1024 x 768 pixels), whereas cellphones and personal digital assistants (PDAs) with only small displays (e.g., 160 x 160 pixels on a Palm) cannot easily fit so much text on a single page. Reading long sentences one-by-one and scrolling in as many as four directions is tedious and taxing (Buchanan et al, 2001).

Another technical difficulty is a lack of interaction methods that are appropriate for the characteristics of mobile devices and mobile environments. Point-and-click dominates the desktop, but is difficult to use on mobile devices, such as cellphones, which instead rely on menus, buttons, and keypad entry for selection and input. Point-and-click does not provide mobile users with easy single-

hand or hands-free operation, and almost certainly decreases productivity (Perry et al, 2001). Moreover, while walking or driving, users often cannot keep visual attention on the display, requiring eyes-free operation.

In this paper, we describe the design and implementation of a system for tailoring web content to mobile devices that addresses both the display size and interaction method problems. This system includes flexible hierarchical menu-based presentation of content to facilitate mobile user tasks, along with simple means for providing audio previews. A middleware component was implemented that facilitates user interaction with the web both on small displays and by voice, and can coordinate interaction among the different input and output channels.

2 Background and Related Work

Many mobile phones today can access the web using the wireless access protocol (WAP), which relies on wireless markup language (WML) to format web content for mobile use (<http://www.wapforum/DTD/>). Mobile devices can obtain WML content through a transcoding proxy that transforms the web's normal hypertext markup language (HTML) to WML. However, because simple tag-to-tag

translation cannot assure appropriate content arrangement on small displays, few users actually use transcoding middleware to access the web on handheld devices (Bowman, 2000). Some commercial systems, for example wmlproxy.google.com, force users to view web pages in small pieces, one at a time. Some PDAs miniaturize pages so that more can be displayed on small screens.

Hierarchical user interfaces (UIs) can be used for navigating contents that are too large to fit on a single screen (Borgman, 1990; Chimera et al, 1994; Buchanan et al, 2001; Feiner, 1988; Furnas, 1986). In this paper, we describe a proxy-based Interaction Manager that parses HTML to create hierarchical menu UIs for mobile users. We pay particular attention to browsing web portals, which is different from the focus of the Power Browser (Buyukkokten, 2001). A web portal organizes links, summaries, and services about particular topics, such as news (e.g., news.yahoo.com), and users routinely visit portals to track the latest information about hobbies, work, and news (Sellen, 2002). Because portals do not provide long text paragraphs, the accordion-like summarization presented by the Power Browser is probably not needed.

To facilitate management of contents (including house-keeping functions, such as updating and deleting links and summaries), portal sites often arrange content in topic areas under chunk tags, such as <table>, <form>, <div>, and so on. Nevertheless, the layout and structure of portal pages can be extremely diverse and complicated. For example, the most popular news portal in China, news.sina.com.cn, presents more than 400 links and about 120 tables in one entry page. Thus, when a user visits such a portal page on a small display, navigating through the large hierarchy to locate the proper chunk will be difficult.

Moreover, mobile device users typically rely on different interaction techniques than desktop users, but few web sites optimize interaction for mobile use. One study found that WAP users were surprised when WAP site navigation did not function like hierarchical phone menus (Buchanan et al, 2001). Some PDAs use a pocket version of Microsoft's Internet Explorer (IE) that is simply a miniaturized version of desktop one. Their users rely on the same desktop metaphor, but use a stylus to click on touch screen rather than a mouse. However, this interaction mode does not support one-hand operation, which a key requirement of mobile users. Our approach is to design keypad-based menu operations for interacting web content.

Current mobile web browsers lack flexibility in selecting input and output modalities, though devices such as mobile phones support multiple communication modes. A user with a minor visual impairment might prefer to hear news rather than to read news on a small screen. And a user "on the move" (e.g., walking or driving), he or she may want to choose different interaction modes at different times. Different contents, different devices, different user contexts, and different environmental factors will lead users to choose different modalities---and to change their

choices frequently (Salzman et al, 2002). Our proxy-based intermediary system (Ma et al, 2002; Maglio et al, 2000) enables mobile users to visit web sites in different modalities, and to switch between modalities at anytime. Our system adds audio feedback to all menu operations, giving users the ability to hear information and to navigate by both oral commands and button presses. In addition, our system provides a unique function that enables mobile users to listen to information before actually navigating through the hierarchy to see it. We designed the visual and auditory components of the interface to complement one another, which seems to be a condition for success of multimodal interfaces (Oviatt, 1999).

In what follows, the design for a mobile web browsing UI is first presented. Second, the middleware-based implementation of the hierarchical menu interface, navigation menu design, and associated auditory interfaces are described in detail. Third, a usability study of the system design and implementation is presented. Finally, conclusions and future research plans are discussed.

3 Mobile Web Browser DESIGN

Over 60% of web activities consist of browsing and information gathering, that is, visiting web sites without a definite idea of what is to be found (Sellen et al, 2002) . Users are loyal to web sites and routinely visit some pages to track updating information (Montgomery et al, 2001). Along these lines, we interviewed 11 people from IBM's China Research Lab to learn what sorts of things they do on the web. Participants were asked to list three web sites that he or she was most familiar with, to describe on how often he or she visits the web site, and to explain why he or she prefers these web sites. The results showed participants routinely visited four kinds of sites (see Table 1): news portals, search engines, communication portals (e.g., chat room, message board, email) and entertainment portals (e.g., literature, games). In addition, all participants access these web sites both from the office and from home.

Table 1: Web sites listed in our survey.

Type of Site	Site	Count
News Portal	sina.com.cn	7
	sohu.com	3
	people.com.cn	1
	jb.com.cn	1
	soufun.com	1
Search Engine	google.com	6
	yahoo.com	2
Communication Portal	chinaren.com	1
	our-yimei.com	1
	mail.263.net	2
	hotmail.com	1
	5460.net	1
Entertainment Portal	chinagames.com	1
	wenxuecity.net	1
	xys.org	1

Our participants had diverse preferences on communication portals and entertainment portals, though surprisingly shared a common interest in one news portal, namely, news.sina.com.cn. Most claimed to visit sina.com at least once a day. This is surprising because there are several other big news portals, such as www.tom.com, www.163.com, www.fm365.com, but no one we interviewed claimed to visit any of these frequently. Figure 1 shows a screen shot of news.sina.com.cn. This entry page can occupy more than 7 screen-fulls that are 1280x1024 pixels in resolution, and with text in a small font size.

The interview results suggest that mobile users would benefit if the contents provided on sina.com could be displayed on a single page. In fact, all the news portals our participants frequently visited are large pages (covering at least 2 full screens with more than 100 links). And loyalty to these large web sites continues after they leave the office, even though most connect to the Internet through a telephone line rather than a high speed LAN at home. Given the apparent importance of these news portals to our participants, it seems worthwhile to develop tools to provide convenient access to these kinds of portals for mobile users.

3.1 Hierarchical Menu Design

On the entry page of news.sina.com.cn, each story is summarized as one line of text and a link to a more detailed page, with summaries organized into coherent information chunks. As mentioned, hierarchical UIs facilitate navigation on small displays. The design of our first prototype incorporates content chunks, hierarchical menus, and presentation style appropriate for small displays.

Content Chunks

In many cases, HTML tags can be used to identify a useful information chunk, such as <table> and <form> tags. However, professional authors of web pages generally use chunk tags for multiple purposes. For example, they use chunk tags to group together coherent contents (what we will call Content Chunks) and to separate the screen into spatial regions (what we will call Layout Chunks). Layout Chunks help group relevant topics together, that is, by nesting relevant content chunks. These chunk types can be distinguished with a heuristic rule: a Content Chunk contains at least one content item (e.g., link, text, or image) that is not contained by a subordinate chunk. This heuristic rule seems to work well in practice; for instance, a content chunk on a news portal will usually contain text summaries of different stories that are likely to have the same relevance or importance to the user.

Hierarchical Menus

There are about 120 content chunks on the entry page of news.sina.com.cn, and 101 of them are independent of one another (i.e., they are not subordinate to any other content chunk). If these were arranged in flat list, it would certainly be tedious to find information by scrolling and by



Figure 1: Screenshot of news.sina.com.cn. The web page provides more than 400 news summaries with associated links to details. It is the most popular news portal in China.

accessing them one by one on a small display. For example, wmlproxy.google.com separates the entry page of sina.com into 88 WML decks (one deck occupies two screens of four-line Chinese text display) and the user accesses these decks one at a time by following their associated deck links. However, even a simple menu with 101 links to content chunks seems impractical. Therefore, we have chosen to present contents hierarchically in a multiple-layer menu. Specifically, we use a layout chunk at the top menu layer to present several content chunks at the second menu layer if all subordinate layout chunks do not contain any two of the content chunks. These layout chunks are labeled with the summary of the first subordinate content chunk. In this way, we build a two-layer hierarchical menu for selecting content chunks.

We examined the effectiveness of this approach on six Chinese news portals and found sensible grouping of all relevant content. The reason is that the portal sites actually encapsulate semantically coherent chunks in the same layout chunk for housekeeping or presentation reasons. Although this approach decreases the number of items of the top menu layer, it hides different content chunks at the top level, adding to the user's cognitive load.

Presentation Style

To facilitate menu selection, we use different background colors for menu items. The colors indicate the amount of text contained in underlying contents, potentially enabling users to avoid extending some small items. In addition, we present menus and contents in different styles:



Figure 2: (a) Screenshot of top menu UI in our first prototype. **(b)** English translation of contents in (a).

details in content chunks are presented on separate pages that contain a “go back” link. Given the different kinds of pages, users can easily recognize the current state, that is, whether the current page is a menu or a content chunk.

Figure 2 illustrates the top menu UI of our first design (English translation on the right).

3.2 Refining the Menu Design

Eight colleagues were invited to test our prototype. They set our system as the proxy of their desktop browser and visited any web sites they liked. We interviewed them by telephone or in person. The major problem we observed was a difference between user expectations of the menu UI and what the actually user obtained. In particular, we found the following problems.

Multiple links for a single menu item

One important function of a portal page is to provide many links. In our first design, users can click to follow a page link on the menu when the anchor text summary seems interesting. In addition, we provide two other links at each menu item, one to extend the menu hierarchy, and another to pre-check subordinate chunks by scrolling the text summaries left to right or by hearing them using text-to-speech (TTS). We found users hesitating when faced with these multiple choices, becoming confused about the different functions though the functions were explained several times. Thus, we simplified the menu design to keep only a single link per item for extending the hierarchy.

Different sites have different styles

Some sites organize contents with a category title into a single chunk, such as a table. For example, people.com.cn uses a <tr> tag to contain a title such as “International News” and successive <tr> tags to contain relevant contents, all contained within a <table> tag. For these sites, users can extend the menu item anchored by the title text to access the content details. Nevertheless, many sites, including sina.com, organize contents and their category title in two separate chunks, one containing the title and the following one containing the contents. This arrangement creates two sequential summaries in the second-layer menu

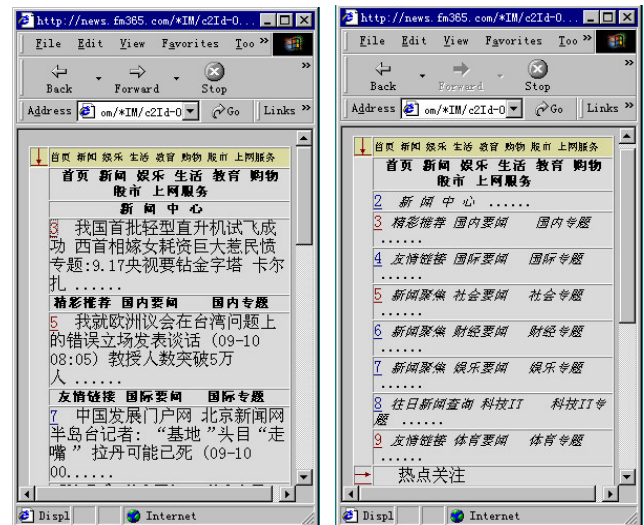


Figure 3: (a) An extended menu: contents and titles are presented in two successive chunks. **(b)** Added heuristic produces uniform menu from the same contents shown

in our original design. Because of this variation, users became confused when switching between different sorts of sites. Thus, we added a specific heuristic to create a single user experience, regardless of this difference on the original sites (see Figure 3).

Too many clicks to uncover details

In many cases, content chunks contain subordinate content chunks. But subordinate chunks cannot be accessed from the menu. In our first design, all subordinate chunks are presented together on a separate page with a link anchored with the text “More details...” in the main content chunk. Our participants told us that there was no information to help them decide whether it is worthwhile to follow this link. We now display the content chunk and subordinate chunks on one page (see Figure 4).

Background colors can be confusing

Most of our participants did not think the background colors had an obvious influence on selection, and several complained that they hesitated because they had to recall what the colors indicated. We redesigned the menu to have a single background color.

3.3 Multimodal Menu Operations on the Cellphone Keypad

Cellphone users are familiar with keypad operations for application selection and for text and number input. Only one hand is needed both to hold the phone and to operate the physical buttons. The physical buttons on a keypad are available anytime, are convenient to map to actions, and are often large enough for thumb operation. Single-hand operation is common in people driving cars and people walking. Single-hand operation enables simultaneity of actions (Perry et al, 2001; Jaureguiberry, 2000), which

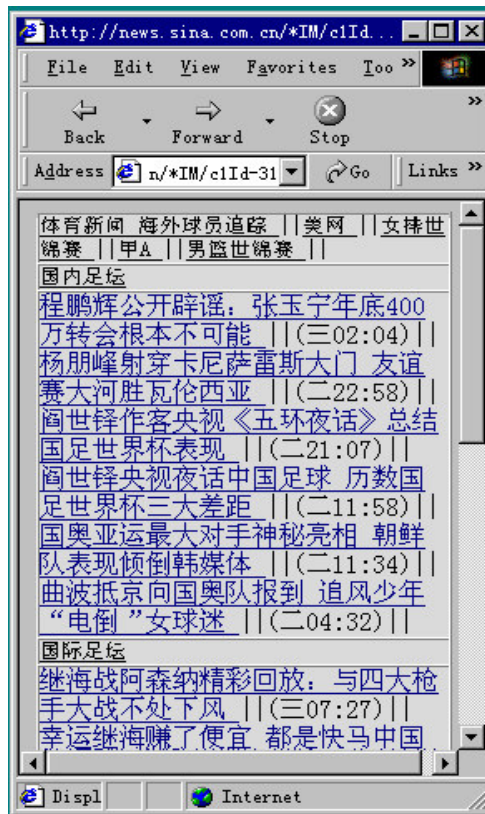


Figure 4: A page presents together a content chunk, Sports News, and its three subordinate content chunks, 1) National Football Game, 2) International Football Game, and 3) General News & Basketball.

increases productivity. In these sorts of mobile contexts, users might prefer to hear information and might also prefer to access information by voice commands, depending on social setting and environmental noise. We designed our prototype based on the typical keypad found on mobile phones.

One-button-browsing

We assume that it is easier for people to say, “one” and “three” in a mobile environment than it is to say “Go deeper” and “Go next”. Moreover, it is easier for current speech recognition engines to recognize digits. To facilitate one-hand operation for users on the move, our approach was to design one-button-browsing with additional, simple speech input to select among a few items in a subordinate menu.

In particular, we use button “0” to scroll menu selection, starting from the first item to the last item and then going back the first item. When the user changes the focus, he or she will hear title of the item. If the user hesitates on an item (i.e., not pressing “0” successively), he or she will hear about subordinate items. The visual UI coordinates automatically with the audio interface, highlighting the current item with focus. When the user presses “0” twice, he or she will hear a detailed description of all the choices on the subordinate menu, and the visual

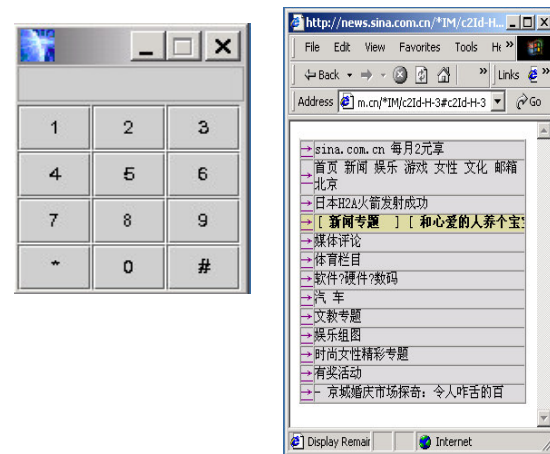


Figure 5: (a) Keypad of DMTF simulator of the Voice-XML browser. (b) Visual UI that highlights the menu focus of the speech channel and displays relevant text simultaneously.

menu is also extended. The user can also verbally say the index of an item to access its content. When the user hears or sees details of a content chunk, he or she can press “0” to go back to the subordinate menu.

Our auditory interface and visual interface complement each other, providing less overlapping information on the top menu. The user can hear spoken messages hidden from the visual interface and also can become aware of menu context quickly by glancing at the display. The auditory messages also save the user clicks in checking each top menu. This interface seems to meet some of the requirements of eyes-free operation for mobile people.

Problems with one-button-browsing

Despite our efforts, there are several problems with multimodal one-button-browsing. Consider that users might visit a page either to find information on the page or to follow links to other pages. To enable link following, we must index each link with a number, which decreases the TTS understandability when the user hears a paragraph containing several embedded links (numbers). Another problem is that the speech recognition engine often notices environment noises, stopping and then restarting TTS in an effort to understand what the user has said. In this case, users sometimes must listen to information over again. To solve these problems, we decided not to display the index of embedded links for content chunks. We added another button, “*,” which will bring up an indexed list of links. For chunk selection, the user can choose to rely on dual tone multi frequency (DTMF) keypad input alone to select numbered links, which helps alleviate speech recognition problems in noisy environments. In most cases, however, users relied on “0” to go through the hierarchical menu. Figure 5 shows a DMTF simulator and our button-based visual interface.

4 User Study

To determine whether our interface and interaction designs for mobile handheld devices are effective, we conducted a user study comparing two variants of our system with unmodified pages displayed in a comparably sized version of IE.

4.1 Method

We compared three situations: our menu-based approach with touch screen interaction, our multimodal menu approach with button interaction, and Internet Explorer sized to fit a handheld display. We measured number of clicks or button presses and time required to find specific information in a series of search tasks, and we collected subjective ratings of the various interfaces as well.

Participants

Fourteen people from our research lab volunteered to participate. None had experience with our system. All had experience using IE and interacting with sina.com, and 10 of the 14 were frequent users of sina.com. Participants ranged in age from 25 to 40.

Design

Each participant used three different interfaces: Menu with Touchscreen (MT), Multimodal Menu with Button (MMB), and plain Internet Explorer (IE). Participants were randomly separated into two groups so that no one saw the same search task in more than one interface condition.

Apparatus & Materials

We implemented a proxy-based Interaction Manager that parses web pages to generate our hierarchical menu in HTML and VoiceXML, and adds Javascript and Java applets to support our interaction functions. The system is installed on a laptop computer with a touchscreen display. We used the IE browser and a VoiceXML browser with associated DTMF simulator to support multiple input/output modes. In all cases, the size of the browser window was set to be the same size as that of a Compaq iPAQ handheld computer, displaying 14 lines of text.

We recorded three pages from news.sina.com on three different days (more than 10 days apart) to serve as data for the study. The Interaction Manager formatted these as appropriate for participants in the three conditions.

Three different sets of six information search tasks were created. Each task required the participant to find a specific piece of information located on the sina.com site. Each task was presented to the participant as a pair of category title and news headline, which the participant was required to find and to read. There are many different categories on sina.com. We chose different categories for the different tasks. Four of each set of six were large categories, containing at least six news items. The two others were small categories, often providing links to different discussion forums or profession-related pages.

A questionnaire was developed for participants to rate how much they liked using the different interfaces, and to compare the interfaces to one another. Participants rated the answers to these on a seven-point scale, with 1 indicating “I strongly disagree,” and 7 indicating “I strongly agree”. There were eight questions:

1. I prefer pressing buttons to tapping on the screen.
2. I like hearing the link previews.
3. I like the menu interface.
4. I like the multimodal interface.
5. I like the IE interface.
6. If I had more training, I think I'd like the menu interface.
7. If I had more training, I think I'd like the multimodal interface.
8. If I had more training, I think I'd like the IE interface.

Procedure

Participants were trained to complete similar information search tasks using the menu interface on 163.com, tom.com and people.com.cn, all popular web portals in China. Training lasted about 15 minutes. Participants were instructed in the use of the DTMF keypad and how the keys map to browsing functions. Participants were then run through conditions, in balanced order. On each trial, we recorded button presses or clicks (including scrolling clicks), and time using special software. After the test, participants filled out the questionnaire. Finally, participants were interviewed (lasting 5 to 20 minutes) to gather additional feedback.

4.2 Results and Discussion

The number of button presses or clicks differed among the three conditions, $F(2,39) = 133.2$, $p < 0.001$. Mean actions per search task was 6.0 for MT, 5.2 for MMB, and 16.5 for IE. Planned comparisons between each pair of conditions showed reliable differences between MT and IE, $t(13) = 12.2$, $p < 0.001$, and between MMB and IE, $t(13) = 16.7$, $p < 0.001$. Thus, both our menu-based designs lead to fewer clicks than the normal pages displayed by IE. Though the difference between the MT and MMB conditions was not reliable, we observed that the multimodal version seemed to require additional clicks when moving among top-level menu items, and that there was less revisiting of menu items because of the auditory previews.

Though the number of actions taken differed among conditions, the amount of time needed to complete a task did not. Mean task completion time was 68.4 s for MT, 60.0 s for MMB, and 60.6 s for IE. It is a little surprising that IE was not considerably faster than the other two, given that it is the browser interface all participants were familiar with.

On the subjective ratings, participants indicated a preference for MT (6.0) over MMB (4.9) and IE (3.5). When asked how additional training would affect their judgments, the same order resulted: MT (5.6), MMB (5.0), and IE (3.6). Participants judged auditory previews as helpful (5.6), and were split on whether buttons or tapping was better (3.8). Overall, the ratings of the novel interfaces were quite high compared to the plain IE browser.

During the interviews, eleven participants said that more training and decreasing latency of our testing systems (2~3 seconds for MMB) would not change their preferences. No participant was satisfied with the quality of our TTS, and listed this as a major reason why they did not prefer the auditory interface to the others. Some mentioned that they were used to clicking when browsing, which perhaps suggests that we should run similar tests on people who are not experienced computer users.

5 Conclusions

Mobile phone and handheld computer users have problems accessing information on portal pages because the organization and interaction methods of portals tend to be optimized for desktop screens. To address these problems, we designed a system for transcoding portal pages for small displays and for mobile input. In particular, we format pages to access content through hierarchical menus, and we enable one-button interaction to select menu items. In addition, we added speech input for selection and speech output to preview content. A user test suggests our interfaces are in fact more efficient than a regular browser on a small screen, and are preferred by users.

In future work, we plan further empirical studies, including field studies, to find appropriate UI techniques for mobile users. Additional comparisons between point-and-click interfaces and our multimodal approach are needed to understand why the time required in our first study for IE was the same as that for the novel interfaces, though IE required far more clicks.

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