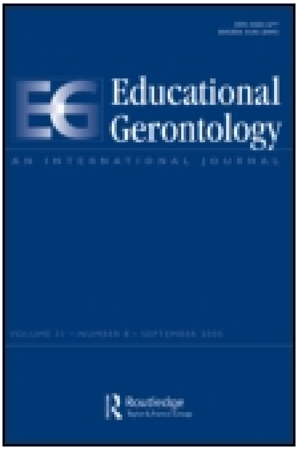

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Interaction Devices and Web Design for Novice Older Users

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INTERACTION DEVICES AND WEB DESIGN FOR NOVICE OLDER USERS

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This study investigated the effects of interaction devices on the Internet performance of novice older users, and ways to provide appropriate voice assistance to enhance browsing and searching performance of such users. Three experiments were designed and conducted to test three hypotheses. The results indicated that touch screen and handwriting recognition are better than mouse and keyboard in browsing time in the third trial. Touch screen was also found to be better in terms of performance time for keyword search tasks than mouse and voice input in the second trial, and is better in terms of user error for keyword search tasks than mouse and voice input in the first trial. Learning effects were found for using touch screen and handwriting recognition, and mouse and keyboard for browsing and searching tasks. Furthermore, voice-menu assistance was associated with higher satisfaction for browsing tasks.

The proportion of older people in the population of many countries has been increasing. At the same time that the population is aging,

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computers are being integrated into many aspects of life and changing work, personal communication, education, and health care. Older people need to interact with computers in many daily life activities; hence, the Internet. There has been increased Internet usage among the older population in recent years. A shifting age ratio combined with the spread of the Internet means that the importance of older users and the importance of user interfaces for older users have increased considerably.

In general, the literature on aging and skills acquisition indicates that older adults have more difficulty acquiring new skills than young people, and they achieve at lower levels of performance. Furthermore, there is substantial evidence about age-related declines in most component processes of cognition including attention processes, working memory, information-processing speed, encoding and retrieval processes in memory, and discourse comprehension (Park, 1992). Therefore, we need to understand the implications of age-related changes in functional abilities for the design and implementation of computer interfaces.

The Internet is a unique type of computer application. The nature of the Internet, which is hypertext, is usually nonlinear, and the freedom and flexibility of hypertext systems are sometimes burdensome to users. Whalley (1993) indicated that hypertext breaks down the notion of coherence and cohesion for the comprehension of linear text. Conklin (1987) indicated that "cognitive overhead" and "disorientation" are the two major problems resulting from hypertext with not enough navigation support. While cognitive overhead is defined as extra effort and concentration to maintain several tasks or trials simultaneously, disorientation is defined as the tendency of losing the sense of location and direction in a nonlinear document (Conklin, 1987). Therefore, it is important to consider the challenges the internet's hypertext information structure presents to older users.

As indicated by Czaja (1996) and Hawthorn (2000), not much attention has focused on older Internet users until recently. As the Internet develops and the number of websites increases, website designers have begun to focus on the needs of older populations. There are now websites available specifically for older users to fulfill their needs for information searches, communication, online shopping, and entertainment. When interacting with websites, older users need to handle various computer interfaces not originally designed for them. This research attempted to investigate the impact of various computer interfaces on browsing and searching the internet among older users. Input or output (I/O) devices such as keyboards, mouses, touch screens, and voice recognition are compared for older Internet users.

OLDER WEB USERS

The U.S. Bureau of the Census (2003) shows that the 55 and over population is around 35 million; about 12% of the total population. Projections are that from 2011 through 2025, the annual percentage increases in the older (65 and over) population will outstrip the increase in the general population by three to four times. By the year 2050, those 65 and over will be around 21% of the total population in the U.S. (Myers, 1985). However, Miller (1996) shows that only a small portion of older computer users use the Internet. The Internet use survey of Morrell, Mayhorn, and Bennett (2000) found that 30.18% of respondents 40 and over (115) are Internet users, whereas only 20.15% (55) of respondents are 60 and over.

In the Web survey of Morrell et al. (2000), middle-aged users were considered to be 40–59, young-old users were considered to be 60–74, and old-old users were considered as 75–92. Hawthorn (2000) was concerned with the 45 and over group because aging effects become noticeable around the mid forties. This research is concerned with the 50 and over group including older middle-aged users and young-old users. The 10th GVU WWW user survey in 1998 (2003) found that 19.4% of Internet users were 50 and over, and 6.3% were 60 and over. Comparing the results of the first GVU WWW user survey in 1994 with the results in 2003, only about 2% of Internet users are 50 and over. The number of older Internet users and the number of Websites for older users are booming. For example, SeniorNet (http://www.seniornet.org/php/) is a nonprofit organization of computer-using adults, 50 and older, providing older adults education for and access to computer technologies.

The learning experiences of older Internet users can be very frustrating. Bow, Williamson, and Wale (1996) suggest that if older users could overcome mouse problems, they would be very positive about using the Internet. Morrel and Echt (1996) argue that older users interested in learning computers and the Internet need training or adaptive techniques to use instructions designed for much younger people. Cody, Dunn, Hoppin, and Wendt (1999) indicate that many older computer users have no prerequisite knowledge for using keyboards and mouses, or have fears of computers. Morrell et al. (2000) found two primary reasons: 1) lack of computer access, and 2) lack of knowledge among older nonusers about using the Internet. Starr, Eggemeier, & Biers (1995) used NASA-TLX to study the effects of aging on working memory and mental workload. They found no differences in working memory, but higher mental workload for older users.

Through appropriate training and learning, older users can enjoy using the Web. Mead, Spaulding, Sit, Meyer, and Walker (1997) indicated that older users could complete most of their web searching tasks but require more steps than their younger counterparts. Cody et al. (1999) trained 292 older adults to learn about computer technologies and surfing the Internet. They found that those who learned to surf the Internet have more positive attitudes toward aging, higher levels of perceived social support, and higher levels of connectivity. If older surfers spend more time on the Internet, their computer efficacy is high, computer anxiety is low, and strong attitudes develop toward aging. Meyer, Sit, Spaulding, Mead, and Walker (1997) examined the effects of age and training on efficiency and preferences in an Internet search activity. They found that older participants were able to complete most of the tasks, but took more steps to find information than younger adults. Across age groups, participants with training took 7.8 steps on average to find a target, as opposed to 9.3 for those without training. Older participants used "index tabs" more than younger ones (9% of actions vs. 3%), and those who had the training used more than those who did not (26% vs. 6%). Also, the only group to significantly use the site map was the older trained group. The training may have encouraged the older adults to take advantage of the site map.

Interaction Design for Older Adults

Providing various input devices can help older adults cope with age-related decline. Ellis, Joo, and Gross (1991) found that older adults made more effective use of a computerized health-care system with a keyboard rather than a mouse. Practice can reduce age-related problems. According to Casali and Chasse (1993), the performance of using mouse, trackball, tablet, keyboard, and joystick for users with arm and hand disabilities was improved by practice. Czaja (1997) suggested that speech recognition eliminates many of the age-related problems such as the visual and movement difficulties with manual input devices. Vanderheiden (1997) suggested offering redundant speech-recognition input options and remote controls for users with visual impairments. Also, providing multisenory controls such as audio tone or vibration, and speech output to read or confirm the setting are suggested.

Avoiding the use of small targets may help older adults. Casali (1992) found that small targets were problematic for physically-impaired users for dragging tasks. Charness, Bossman, and Elliot

(1995) reported that older adults learning a graphic user interface committed a greater number of mouse errors than younger people, and that they had particular difficulty with smaller targets. Also, they found that older adults exhibited longer response times with the mouse for both clicking and dragging tasks compared to the light pen. Older adults require more practice than younger people with small targets.

Michael, Smith, Sharit, & Czaja (1999) suggested using extra feedback and hints for older users to conduct visual search tasks. Age-related visual declines such as reductions in light sensitivity, cooler perceptions, resistance to glare, dynamic and static acuity, contrast sensitivity, visual search, and pattern recognition (Kosnik, Winslow, Kline, Rasinski, and Sekuler, 1988) have an impact on the usage of computer user interfaces. Using big fonts and high-contrast display are helpful to aged people. Website designers should also avoid glare and rapid change in brightness. Hedman and Briem (1984) found a slightly higher incidence of eyestrain among a group of older telephone operators using computer terminals. Kosnik, Winslow, Kline, Rasinski, and Sekuler (1988) suggested avoiding moving text and providing ample time to read any text presented. Charness, Schumann, and Boritz (1992) reported that the majority of older participants experienced some difficulty in reading the screen, and that these difficulties may have contributed to the lower performance of older adults in computer tasks such as word processing. Charness, Bosman, and Elliot (1995) reported that target size affects the ability of older adults to perform transactions like clicking and dragging using a mouse and light pen. Charness (1998) observed that older users have difficulties understanding the difference between a mouse-position indicator and an insertion-point indicator.

Charness et al. (1992) indicated that menus and menus with icons were better for older users because of low memory loading. Pop-up windows or multiple windows were not suggested for older users, because of their effect on aging memory and spatial ability. Hawthorn (2000) found that older users have disorientation problems while using scrollbars. The aging effect on psychomotor ability also has impact on using scrollbars and imaging maps for older users (Meyer et al. 1997).

HYPOTHESES AND METHODOLOGY

Hypotheses

This research investigated Internet-user-interface design for aging users, and the effect of interaction devices on browsing and searching

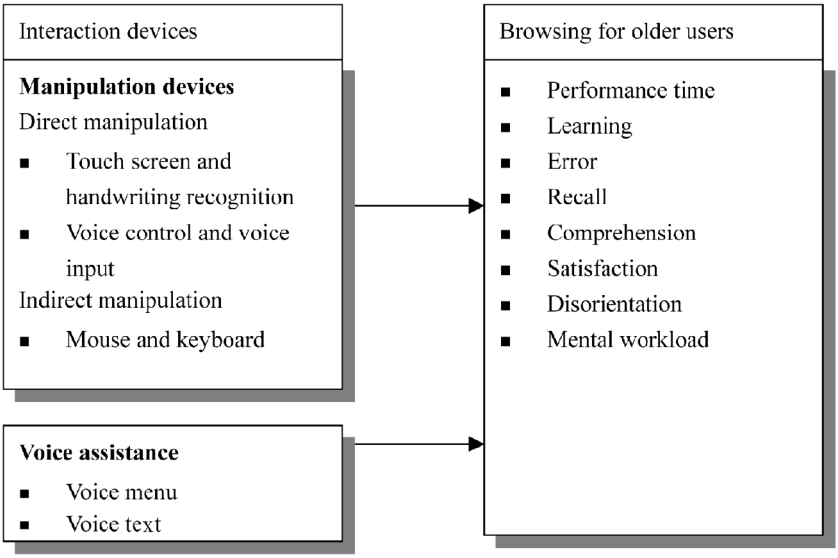

FIGURE 1 Research framework and hypotheses.

for older users (Figure 1). Interaction devices included manipulation devices and voice assistance. There are three levels of manipulation devices in this study: 1) touch screen and handwriting recognition 2) voice control and voice input, and 3) mouse and keyboard. There are two levels of audio assistance in this study: 1) voice menu, and 2) voice text. The impact of different input devices and voice assistance on browsing performance factors of older users was studied. Factors studied included performance time, learning, error, recall, comprehension, satisfaction, disorientation, and mental workload.

Hypothesis 1

For older novice users (50–70), browsing performance will be better with direct-manipulation devices (touch screen and handwriting, and voice control and voice input), than with indirect-manipulation devices (mouse and keyboard).

Ellis, Joo, & Gross (1991) recommended use of touch screens to help older users. Czaja (1997) recommended speech-recognition interfaces to eliminate age-related visual problems and movement difficulties with manual-input devices. However, voice control requires more working memory than hand-eye coordination (Czaja, 1997). It is hypothesized that older users will perform better with direct-manipulation input devices than indirect-manipulation input devices for browsing.

Hypothesis 2

For older novice users (50–70), keyword search performance will be better with direct-manipulation devices (touch screen and handwriting, and voice control and voice input) than with indirect-manipulation device (mouse and keyboard). Also, keyword search performance will be better with touch screen and handwriting than with voice control.

Searching involves keyword input and information browsing tasks. Leggett and Williams (1984) found that voice input is slower than the keyboard for word processing, but more accurate. Danis, Comerford, Janke, Davies, DeVries, and Bertran (1994) indicated that using voice input instead of mouse and keyboard may disrupt the user's problem-solving process. It is hypothesized that older users will perform better with direct-manipulation input devices than indirect-manipulation input devices for keyword search. Touch screen and handwriting are associated with better performance for keyword search than voice control.

Hypothesis 3

For older novice users (50–70), browsing performance will be enhanced with voice-menu assistance and voice-text assistance.

Vanderheiden (1997) suggested offering a redundant speech-recognition input option and remote controls for users with visual impairments. Also suggested are providing multisensory controls such as audio tone or vibration, and speech output to read or confirm the setting. Both Hawthorn (2000) and Zajicek (2001) indicated that short voice messages are helpful for memorization by users, particularly older users. Zajicek and Hall (2000) also found that older users have problems concentrating on long voice assistance messages, because such messages are difficult to memorize. Albers and Bergman (1995) found that providing voice assistance for users' activities and content does not disturb Internet users. Nielsen (1996) recommended utilizing text-to-speech techniques to help users with vision impairments for browsing. Zajicek (2001) suggested examining the effect of voice assistance for content on the performance of older users. It is hypothsized that providing voice assistance can enhance the browsing capabilities of older users.

EXPERIMENT ONE

To test the three hypotheses, three experiments were designed and conducted.

Participants

Twenty-four novice users 50–70 were engaged in the experiment. Participants were randomly assigned into one of three groups (touch screen, voice control, and mouse). The average age of the participants in the touch-screen group was 60.9 years ($SD = 7.40$); the average age of the participants in the voice-control group was 55.1 years ($SD = 5.69$); the average age of the participants in the mouse group was 57.3 years ($SD = 4.74$). Seven participants in the touch-screen group had no prior experience using touch screen; seven participants in the voice control group had no prior experience using voice control; six participants in the mouse group had no prior experience using mouses. Most participants were novice users of the input devices in the experiment.

Apparatus

A notebook computer with a touch screen and voice control function was used for the experiment. Each participant was required to perform the tasks independently, using the assigned manipulation device for pointing and selecting, with no other participants present except for the experimenter. The participants' movements throughout the system were automatically timed to the nearest .001 s and traced by a keystroke-capturing program on the computer. The testing hypertext system (Figures 2 & 3) consists of seven categories and 20 articles.

Experimental Design and Variables

The independent variable was the manipulation device. Three levels of the manipulation were: 1) touch screen and handwriting recognition, 2) voice control and voice input, and 3) mouse and keyboard. This study used six dependent variables: performance time, learning, user error, satisfaction, disorientation, and mental workload. Performance time was defined as the total time taken to complete the required browsing task. The performance times were collected for tasks performed by each participant. Time was recorded by the testing hypertext system to the nearest .001 s. Learning was measured by comparing the performance time of three consecutive trials of tasks. The user error was defined as the total number of steps that a participant required for the tasks minus the steps of the optimal path. Satisfaction was defined as the score obtained through a satisfaction questionnaire consisting of 14 questions (Cook, 1991) rated on the scale of 1 (lowest satisfaction) to 7 (highest satisfaction). Disorientation was defined as the score obtained through a questionnaire

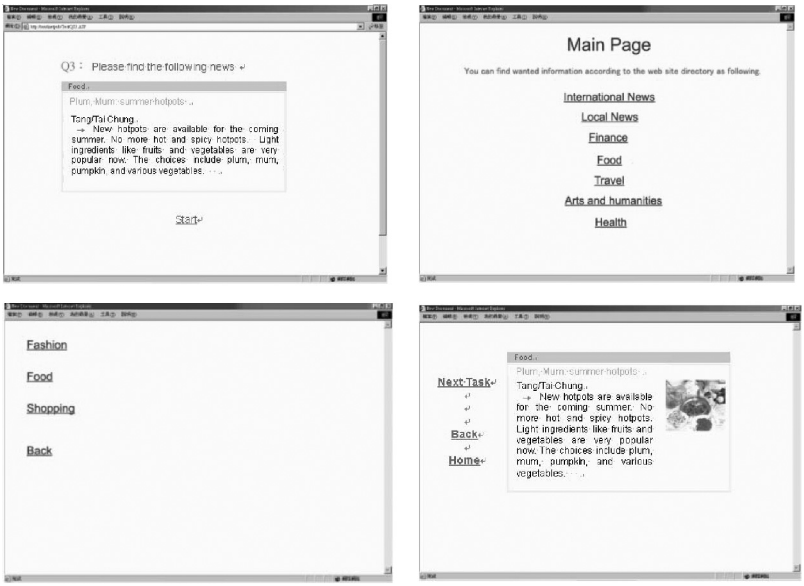

FIGURE 2 User interface of the testing system of experiment one.

International news	World
	U.S.
	Europe
Local news	North
	Central
	South
Finance	Stock markets
	Personal finance
	Tax
Food	Fashion
	Food
	Shopping
Travel	Domestic
	Abroad
	Outdoors
Arts and humanities	Music
	Art
	Stage
Health	Health knowledge
	Health news

FIGURE 3 Information architecture of the testing system of experiment one.

consisting of 10 questions (Beasley & Waugh, 1995) on the scale of 1 (strongly disoriented) to 5 (never disoriented). The lowest score was 10, meaning completely disoriented; the highest score was 50, meaning not disoriented. Mental workload was measured by a questionnaire based on NASA-TLX (Hart & Staveland, 1988) consisting of six factors: mental demand, physical demand, temporal demand, performance, effort, and frustration level.

Tasks

The information-browsing tasks on a testing computer system were designed. Participants were asked to read one article and then to navigate to the relevant web page in the testing hypertext system. There were three consecutive trials of tasks for each participant, with six general browsing tasks (Cove and Walsh, 1988) in each trial. Each participant was given three trials in the same sequence. The tasks to be performed were the same in each session, but in different orders.

Procedure

All participants began by filling out a general-information questionnaire concerning their personal characteristics including age, education, and past computer and internet experience. Each participant was given on-screen instructions, depending on the type of manipulation the participant was assigned. A brief practice session was then conducted to help the participants understand the operation of the system and the tasks to be performed. Following the practice, each participant performed three consecutive trials with six information-browsing tasks in each trial. The participants were instructed to perform the tasks as quickly as possible without sacrificing accuracy. On the completion of the tasks, each participant was given three questionnaires about satisfaction, disorientation, and mental workload.

EXPERIMENT TWO

The second experiment was designed to test hypothesis two. The number of participants and the procedure were the same as in experiment one.

Apparatus

The testing hypertext system was a keyword search system as shown in Figure 4.

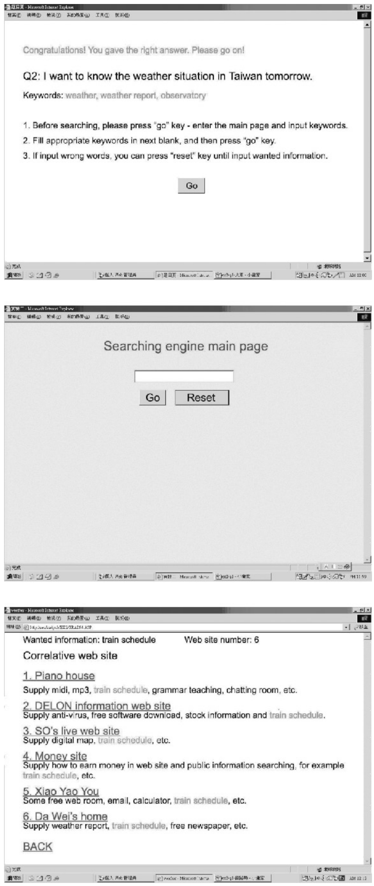

FIGURE 4 User interface of the testing system of experiment two.

Experimental Design and Variables

The independent and dependent variables were the same as in experiment one except for user error. User error was defined as both the total number of steps that a participant required for the tasks minus the steps of the optimal path, and the frequency of wrong query input.

Tasks

The keyword-search tasks on a testing computer system were designed. There were three consecutive trials of tasks for each participant, and six keyword-search tasks in each. The six keyword-search tasks required users to find information about train schedules, weather, hotels, flight schedules, the stock market, and movies. Each participant was asked to choose keywords from a list provided by the testing computer system for each task. Each participant was given three trials in the same sequence. The tasks to be performed were the same in each session, but with items listed in different orders.

EXPERIMENT THREE

The third experiment was designed to test hypothesis three.

Participants

Sixteen novice users aged 50–70 were engaged in the experiment. The participants were randomly assigned into one of the two groups (voice-content assistance versus no voice-content assistance).

Apparatus

The testing hypertext system (Figures 5 and 6) consisted of 8 categories and 32 articles in total.

Experimental Design and Variables

The independent variables were voice-menu assistance and voice-content assistance. The voice-menu assistance was within-subject and voice-content assistance was between-subject. The two levels of voice-menu assistance were with voice-menu assistance, and without voice-menu assistance. The two levels of voice-content assistance were with voice-content assistance and without voice-content assistance. This study used six dependent variables: performance time, reading time, cued recall, reading comprehension, satisfaction, disorientation, and preference. Performance time, satisfaction, and disorientation were defined the same as in the first experiment. Reading time was defined as the time taken to read the required information. Cued recall was measured by a cued-recall memory test. Reading comprehension was measured by a reading-comprehension test with ten questions. Preference was measured by one question scoring from 0 to 100 for participants' preference for the system.

Tasks

Twelve information-browsing tasks on a testing computer system were divided into two sessions. The participants were asked to browse six

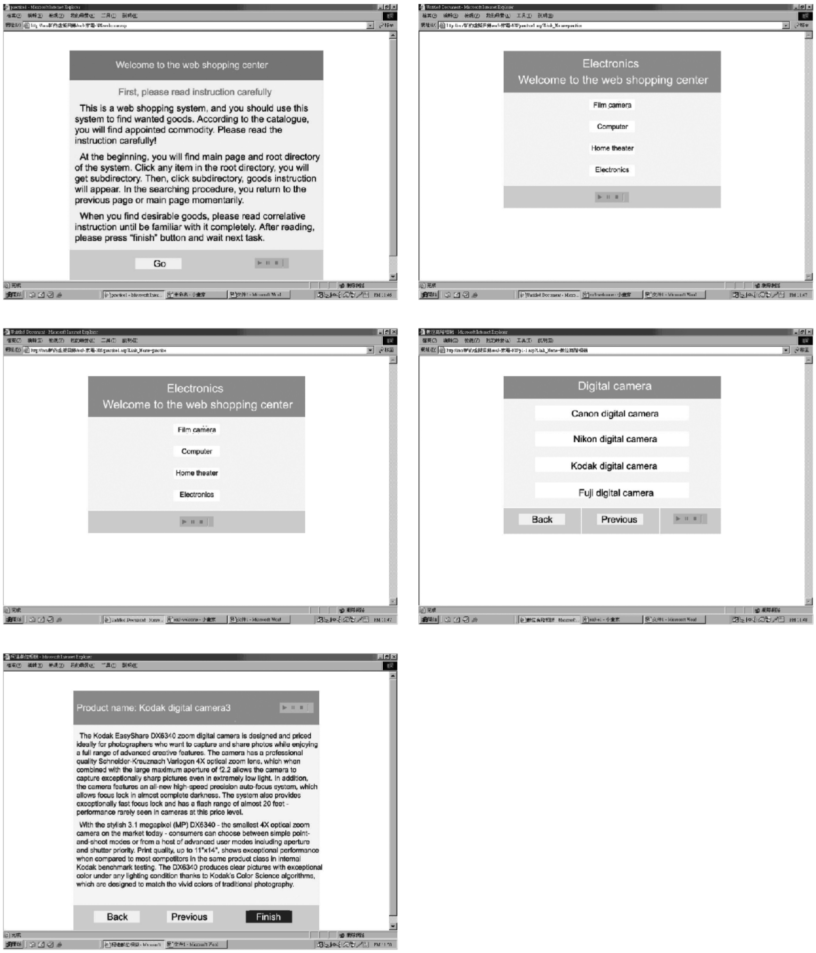

FIGURE 5 User interface of the testing system of experiment three.

information-technology products and link to the introduction of those products in each session.

Procedure

All the participants began by filling out a general-information questionnaire concerning their personal characteristics including age, education, and past computer and internet experience. Each participant was given on-screen instructions, depending on the type of manipulation the participant was assigned. A brief practice session

Camera and photo	Professional digital camera
	Digital camera
	Camcoder
	Accessories
Computers	Desktop
	Laptop
	Peripherals
	Monitors
Audio and video	Audio
	Digital voice recorder
	MD and MP3 player
	Portable CD player
Electronics	Kitchen blender
	Coffee maker
	Hair dryer
	Iron
Books	Business
	Young adults and children
	Art and culture
	Family and health
Magazines I	Finance
	News
	Fashion
	Language
Magazines II	Sports
	Health
	Literature and arts
	Home
Music	Pop
	Classic
	Jazz
	New age

FIGURE 6 Information architecture of the testing system of experiment three.

was then conducted to help the participants understand the operation of the system and the tasks to be performed. Following the practice, each participant performed the six information-browsing tasks without voice-menu assistance. The participants were instructed to perform the tasks as quickly as possible without sacrificing accuracy. On the completion of the tasks, each participant was given three questionnaires about satisfaction, disorientation, and preference. The second section of the experiment was then conducted with voice-menu assistance.

RESULTS AND DISCUSSION

Testing Hypothesis One

The background information of the participants was first compared. Significant differences were found in education, computer experience, and Internet knowledge. Thus, these three factors were considered as covariates. The data collected were checked for model adequacy. The data were transformed if model adequacy did not hold. Nonparametric analysis was conducted for the middle-range search-browsing tasks because the model adequacy was not held after transformation.

The intention of hypothesis one was to examine how the manipulation device might influence browsing for older novice users. A significant difference in the third trial of performance time ($F = 6.91$, $p = 0.0050$) was as shown in Table 1 (Figure 7). According to the results of Duncan's multiple range test, the difference of performance time between touch screen and handwriting recognition, and mouse and keyboard in the third trial was significant ($F = 10.86$, $p = 0.0034$). The learning effect of performance time was significant. For group one (touch screen and handwriting recognition), there was a significant difference between the first trial and the third trial ($t = 2.483$, $p = 0.042$). For group three (mouse and keyboard), there was a significant difference between the first trial and the second trial ($t = 3.103$, $p = 0.017$), and the first trial and the third trial ($t = 3.275$, $p = 0.014$).

Hypothesis one was partially supported for older novice users. Browsing performance will be better, in terms of shorter performance time, with a direct-manipulation device (touch screen and handwriting, and voice control and voice input), than with an indirect-manipulation device (mouse and keyboard) in the third trial. Touch screen and handwriting recognition were found to be the fastest

TABLE 1 Data for Testing Hypothesis One

		Touch screen and handwriting recognition		Voice control and voice input		Mouse and keyboard			
Variables	Trial	Mean	*SD*	Mean	*SD*	Mean	*SD*	F	*p*
Performance time (s)	1	220.526	111.688	338.278	191.604	392.580	149.763	2.59	0.0986
	2	192.548	97.069	250.358	82.182	256.083	61.078	1.49	0.2484
	3	126.252	34.402	236.748	104.186	231.311	63.992	6.91	0.0050*
User error	1	2.4	3.38	2.3	1.91	1.9	2.75	0.07	0.9309
	2	3.3	6.92	1.3	2.38	0.3	0.70	0.41	0.6984
	3	2.9	6.58	1.1	2.10	1.6	1.92	0.38	0.6994
Satisfaction		5.3	0.80	5.1	0.70	5.3	0.68	0.38	0.6853
Disorientation		21.8	4.65	22.5	3.74	22.9	6.47	0.10	0.9038
Mental workload		45.5	16.52	45.0	10.92	47.6	14.84	0.07	0.9301

*$p < 0.05$

among the three manipulations after learning. No significant differences were found with user error, satisfaction, disorientation, and mental workload.

Testing Hypothesis Two

The intention of hypothesis two was to examine how the manipulation device might influence keyword-search performance for older novice users. Significant differences were found in the second trial of total performance time ($F = 6.83$, $p = 0.0055$), the third trial of total performance time ($F = 6.43$, $p = 0.0070$), and the first trial of user errors ($F = 6.87$, $p = 0.0070$), as shown in Table 2 (Figure 8). However, a significant difference in the third trial of total performance time disappeared when education was a covariate ($F = 2.39$, $p = 0.1184$). According to the results of the planned contrast test, the difference in the second trial of total performance time of touch screen and handwriting recognition against mouse and keyboard was significant ($F = 12.19$, $p = 0.0023$). The difference in the third trial of total performance time of touch screen and handwriting recognition against mouse and keyboard was also significant ($F = 7.53$, $p = 0.0125$). Furthermore, the differences in the second trial of total performance time of touch screen and handwriting recognition against voice control and voice input ($F = 8.89$, $p = 0.0074$), and in the third trial of total

TABLE 2 Data for Testing Hypothesis Two

		Touch screen and handwriting recognition		Voice control and voice input		Mouse and keyboard			
Variables	Trial	Mean	*SD*	Mean	*SD*	Mean	*SD*	F	*p*
Total performance time (s)	1	387.889	189.768	495.183	295.175	642.189	132.194	2.90	0.0781
	2	275.603	66.277	362.086	232.508	504.613	114.837	6.83	0.0055*
	3	268.211	97.412	253.969	76.630	402.470	93.005	6.43	0.0070*
Number of user Errors	1	0.75	1.165	1.71	1.80	0.43	0.79	6.87	0.0070*
	2	0.75	0.89	1.14	0.90	0.43	0.53	0.47	0.6320
	3	0.88	1.13	0.67	1.21	0.14	0.38	0.81	0.4682
Satisfaction		5.21	0.86	5.18	1.34	5.30	0.88	0.10	0.9053
Disorientation		23.88	5.49	22.88	7.77	23.63	5.07	0.04	0.9640
Mental workload		61.25	18.57	56.08	17.51	56.67	11.12	0.27	0.7628

$^*p < 0.05$

performance time of touch screen and handwriting recognition against voice control and voice input ($F = 10.15$, $p = 0.0046$) were both significant, based on the results of the planned contrast test. Moreover, the difference in the first trial of user error between touch screen and voice control ($F = 5.53$, $p = 0.0318$), and of voice control and voice input against mouse and keyboard ($F = 13.43$, $p = 0.0021$) were both significant, based on the results of the planned contrast test. The learning effect of performance time was also significant. For group one (touch screen and handwriting recognition), there was a significant difference between the first trial and the third trial ($t = 2.883$, $p = 0.024$). For group three (mouse and keyboard), there was a significant difference between the first trial and the second trial ($t = 4.719$, $p = 0.002$), the first trial and the third trial ($t = 13.658$, $p = 0.000$), and the second trial and the third trial ($t = 5.451$, $p = 0.001$).

Hypothesis two was partially supported for older novice users The keyword search performance will be better, in terms of shorter performance time, with a direct-manipulation devices (touch screen and handwriting, and voice control and voice input), than with indirect-manipulation devices (mouse and keyboard) in the second and third trials. Older users using touch screen and handwriting recognition as well as mouse and keyboard committed fewer errors than those using voice control and voice input in the early stage of testing. According to Bass (2001), the user error of voice input was higher than lack of context. Also, the result is consistent with previous research (Kalasky, Czaja, Sharit, Nair, 1999) that the user error of voice recognition for older users was significantly different only for the first two of five trials.

Testing Hypothesis Three

The intention of hypothesis three was to examine how voice assistance might influence browsing for older novice users. Significant differences in performance time ($F = 5.39$, $p = 0.0359$) and reading time ($F = 12.54$, $p = 0.003$) were found as shown in Table 3. Also, a significant difference was found in satisfaction ($F = 17.67$, $p = 0.009$) as shown in Table 4. Hypothesis three was not partially supported for older novice users. Voice-menu-assistance users were more satisfied with browsing than their counterparts without voice-menu assistance. Voice-content assistance required longer performance time, but did not help participants' comprehension and recall. The fact that the participants in this experiment were not very old ($M = 53.1$ years) may be the major reason for the results of voice-content assistance. Also, the

TABLE 3 Data for Testing the Effect of Voice-content Assistance

	No voice-content assistance		Voice-content assistance			
	Mean	*SD*	Mean	*SD*	*F*	*p*
Performance time	470.020	106.830	666.25	248.69	5.39	0.0359*
Reading time	267.867	92.555	455.33	152.58	12.54	0.0033*
Cue recall	13.3	7.25	17.31	7.29	1.61	0.2255
Reading comprehension	52.1	20.07	48.96	28.20	0.09	0.7697
Satisfaction	5.2	0.64	5.22	0.55	0.03	0.8595
Disorientation	22.4	5.57	25.98	6.84	1.25	0.2816
Preference	70.3	24.12	70.31	16.88	Z = 0.784	0.4329

*$p < 0.05$

TABLE 4 Data for Testing the Effect of Voice-menu Assistance

	No voice-menu assistance		Voice-menu assistance			
	Mean	*SD*	Mean	*SD*	*F*	*p*
Performance time	577.876	196.885	575.85	256.86	0.90	0.3601
Reading time	350.733	127.764	371.89	148.29	0.33	0.5737
Cue recall	75.00	15.38	65.63	24.14	Z = −1.109	0.2673
Reading comprehension	15.31	7.85	15.31	7.25	0.33	0.5773
Satisfaction	40.63	21.05	60.42	23.47	17.67	0.0009*
Disorientation	5.44	0.43	4.96	0.64	0.06	0.8110
Preference	24.19	4.98	24.19	7.71	0.96	0.3429

*$p < 0.05$

font of content in this experiment was enlarged so that voice-content assistance was not so helpful as it might have been with smaller type.

CONCLUSIONS

Touch screen and handwriting recognition were better than mouse and keyboard in browsing time in the third trial. For touch screen and handwriting recognition, there was a learning effect in browsing time between the first trial and the third trial. For mouse and keyboard, there was a learning effect in browsing time between the first trial and the second trial, and the first trial and the third trial.

Touch screen and handwriting recognition were better in terms of performance time for keyword-search tasks than voice control and

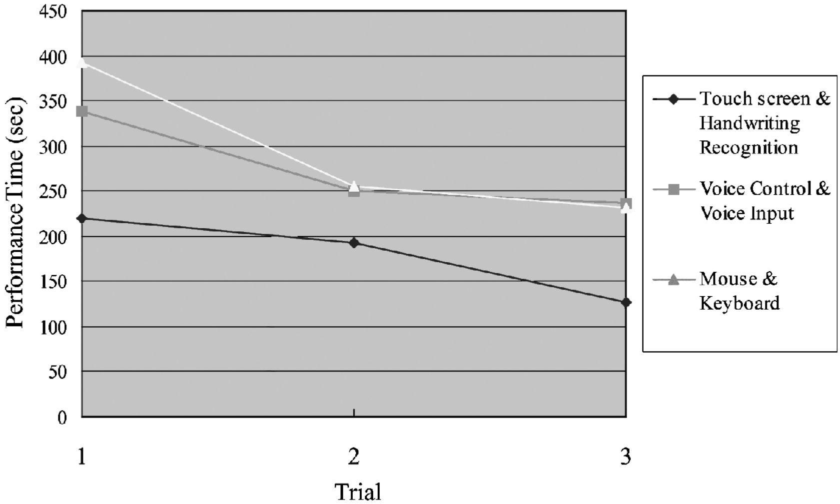

FIGURE 7 Results of performance time in experiment one.

voice input, and mouse and keyboard in the second trial. Touch screen and handwriting recognition were better in terms of user error for keyword-search tasks than voice control and voice input, and mouse and keyboard in the first trial.

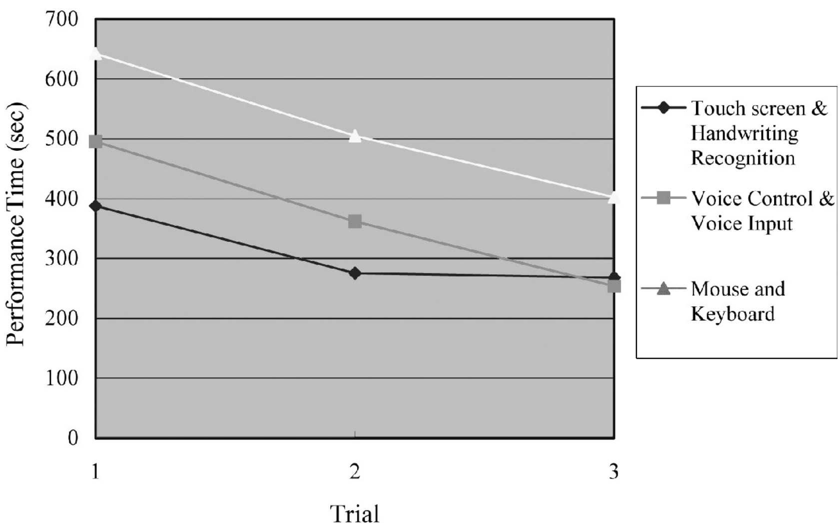

FIGURE 8 Results of performance time in experiment two.

For touch screen and handwriting recognition, there was a learning effect in performance time for keyword-search tasks between the first trial and the third trial. For mouse and keyboard, there was a learning effect in performance time for keyword search tasks between the first trial and the second trial, the first trial and the third trial, and the second trial and the third trial.

Voice-content assistance was found not helpful for recall, comprehension, and satisfaction, but resulted in longer reading time. Voice-menu assistance was associated with higher satisfaction for browsing tasks.

According to the results, the touch screen and handwriting recognition, and voice control and voice input, used in the study were useful for novice older users. These results, however, need to be interpreted with caution given that the data were collected under highly-controlled conditions. The system needs to be tested over a broader array of conditions. Furthermore, the system needs to be evaluated in actual task conditions where the people are required to integrate other input/output modalities. From the results of this study, the direct-manipulation methods are effective on browsing and searching for novice older users. With the spread of mobile technology and the Internet, older people will use personal computers, mobile phones, and other information appliances to connect to the Internet. The results of this study may also be applied to the design of interaction devices for handheld devices, such as mobile phones and personal digital assistants.

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