A Comparison of Navigation Performances between Older and Young Adults in Hypermedia E-Mall Shopping

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Abstract. To facilitate equal access to online shopping for all users, the present study examined if age-related differences in E-mall navigation exist as a function of web presentation media and web structure. 14 older adults and 14 college students participated in an experiment where E-mall shopping navigation was evaluated in terms of the number of pages repeated visited, and retention accuracy. Two experimental E-malls that built on a hierarchical and a referential topology respectively were developed. Each E-mall consisted of 15 pages of product information, which were evenly assigned to three types of presentation media, namely, pure text, static picture and animation. Results indicated that older adults were at disadvantage then their younger counterparts for both performance measures. Despite the navigation difficulty, the older participants nevertheless improved their orientation and retention when the website was displayed by a pictures-based medium on a hierarchical topology. Implications for the design of E-mall interfaces that accommodate age-related differences were discussed.

1. INTRODUCTION

The expanding power of the Internet has brought forth a new generation of interaction platforms between humans and computers. One major development from the technology is the E-commerce where conventional shopping activities can nowadays be carried out simply by fingertip clicks in a virtual digital space. By displaying products and services in an E-mall, the computerized network medium enables a wider array of merchandise presentation (e.g., multimedia and/or virtual reality) and economics transaction (e.g., fixed-priced e-malls or auction houses).

E-commerce is a very specific domain in human-computer interaction and web page design. Helander and Khalid [2000] proposed a systems model that consists of three aspects of design considerations for E-commerce interface, including the web technology, the web environment and the customer. The web technology refers to those technological features employed to present merchandise in a store environment. These features range from browsable web sites, through 3D virtual reality stores, to e-mail trading systems [Miles 2000]. The web environment refers to important design features that would affect customers' willingness to purchase such as navigation facility, product information, feedback information and promotion, etc. The customer component involves those user characteristics that would influence human information processing, including perception, decision-making and action.

With respect to the web technology, the interest of the present study mainly focuses on the use of hypermedia to exhibit an E-mall. Hypermedia is a class of computer technique that utilizes multimedia programs to display information built on hyper-linked data topology [Nielsen 90]. The presentation channels of multimedia normally fall into the major categories of text, static pictures, animated graphs, sound and other computer programs [Picher 91]. The use of multimedia intends to foster various interactions that a text-only interface is unlikely to achieve [Weiss 02] and can be considered as cognitive tools that extend senses [Buchanan 93]. For example, the movement and trajectory features of multimedia presentations enable visualization and clarification of those procedures and concepts that are difficult to

understand. An animated object can also gain attention of the users and signal to them salient points.

The other component of the hypermedia technology is the hyperlink system (i.e., hypertext). Hypertext is a type of information structure where data are represented by nodes and these nodes are connected by explicit links. With this prominent feature, users perusing hypertext can extend their control as to which part of the text they wish to visit and therefore can access a larger amount of information rapidly [Conklin 87]. Nevertheless, this non-linear linking advantage also brings with it some associated problems. The most cited difficulty in the use of hypertext has been the disorientation problem [Kim 95]. Hypertext disorientation refers to the situation where users delve into a network of cross-references, without knowing where and how to get back on original navigation routes. The severity of this navigation problem largely depends on the type of text topology built in the system. McDonald and Stevenson [98] indicated that a referential topology, which takes the form of multiple data linkage, is more likely to result in disorientation than its organizational counterpart, which builds data connection on a rigid hierarchy. Although a successful purchase in a web environment is made on a series of different decisions [Helander 2000], the hypertext disorientation leads the present to examine only those shopping behavior that involves navigation.

As far as the customer is concerned, although the empirical evidence of human performances in these major information platforms has well been documented, data on how older people would react to the new information tools are still limited. The rationale behind the attention paid to this particular user group is derived from the concurrent trends of population ageing and increased integration of the Internet into our daily living. This motivation is also to advocate the National Research Council [97] that stressed the importance of assuring equal access to digital resources for all users.

Research on cognitive aging has indicated that certain aspects of human information processing abilities are negatively correlated with age [Kelly 95]. Specifically, Park [2000] summarized four basic mechanisms accounting for age-related decline in cognitive functions, namely, processing speed, working memory, inhibition and sensory function. The processing speed theory suggests that nearly all age-related variance on almost any kind of cognitive tasks can be explained by a generalized, decreased speed of performing mental operations [Salthouse 96]. Another index of cognitive decline with age is that nearly all of the age-related variance was mediated by human sensory functioning, including visual and auditory acuity [Lindenberger 94]. Craik and Byrd [82] suggested that older adults were deficient in terms of the on-line cognitive resources available at any given moment required for information processing activities involving storage, retrieval, and transformation. Hasher [91] proposed that with age, people will have more difficulties in focusing on target information and inhibiting attention to irrelevant material.

In light of the declined cognitive abilities for older adults, the following queries arise. These queries begin with a fundamental one: Are older adults really less oriented as compared with their younger counterpart in navigating a hypermedia E-mall? Can the elderly benefit from the use of multimedia? Specifically, does it help to add pictures, including static graphs or animation for older adults to enhance their retention of perused web contents? If yes, to what extent the improved retention can help relive the older customer's disorientation problem so that the navigation performances between the two cohorts are comparable? Would the impacts of multimedia-based presentations, if any, vary with the types of text topology? By addressing these issues, the current study aims at examining whether age-related differences exist in navigation performance of multimedia E-mall shopping in relation to web topology.

2. METHODOLOGY

2.1. Subject

14 elderly people and 14 young adults participated in the experiment and their ages ranged from 62 to 80 years old and from 20 to 27 years old respectively. The younger subjects were undergraduates and graduate students of a local university and they all had more than one year of constant web browsing experience. The older subject pool was a computer class administered by a local social welfare institute. The education levels of the senior subjects varied from primary school to college but only those who had at least one year of constant web experience were recruited. Besides, neither subject group had done E-shopping prior to participation of this experiment. Both of the subject groups were paid at the hourly rate of 300 New Taiwan Dollars (approximately 8.00 Euro Dollars) for participation.

2.2. Experimental Design

Age, presentation media and web topology were designed as the independent variables. Age was a quasi between-subject factor, defined by the older and younger groups described above. In order to minimize those individual differences except age, both presentation media and web technology were designed as a within-subject factor (i.e., repeated-measured variable) so that each subject can act as his/her own control to block potential extraneous confounding. The media factor comprised three presentation treatments, including pure text, static pictures, and animation. Topology was defined by hierarchical and referential web structures and details will be provided in the Material section. The subject's navigation performance was measured by retention accuracy and the number of web pages repeatedly visited. Note that backtrack moves were excluded for the hierarchical treatment. As hypertext browsing normally takes place in a self-paced manner, the retention accuracy should take into account how long the subject peruses the document. Accordingly, an adjusted retention score [Ogozalek 94] was adopted where the number of questions answered correctly by each subject was multiplied by the ratio of the subject's actual perusal time to the averaged perusal time of the age group the subject belonged to. The mathematical form of this operational definition is as follows:

$R_s = N_s \ (T_s / MT_g)$, where

R_s = the adjusted retention score for subject s

N_s = the number of questions answered correctly by subject s

T_s = the perusal time spent by subject s

MT_g = the mean perusal time for the age group subject s belonged to, g = older or younger

2.3. Material/The Hypermedia E-mall systems

The material was two experimental E-mall systems that were developed by the hierarchical and referential topologies respectively. Each set of the E-malls consisted of 15 data nodes where each node (page) was associated with one product. The hierarchical E-mall organized these 15 nodes in a rigid hierarchy that connected with each other with parent-child links, whereas the referential E-mall allowed all the nodes to connect to each other by hyperlinks. For both E-mall systems, the 15 data nodes were evenly assigned to the three types of presentation media. Specifically, one third of the 15 nodes of product information were displayed by animated descriptions on salient product features (see Figure 1). The remaining 10 nodes of product information were split such that one half presented the information by

text-only descriptions with the salient features in boldface, and the other half displayed the contents by text plus static pictures associated with the salient functions (see Figure 2). The IE Explorer was employed to display the E-malls. Clicking the button of "Previous page" of the Explorer carried out the maneuver of web pages for the hierarchical mall, whereas the connection of pages for the referential mall was achieved by clicking on the referential nodes (i.e., other products) listed below. The order of assigning these products nodes to the three different media was randomized. The merchandise information for both sets of E-malls was fabricated so that the possible extraneous effect of product familiarity was minimized.

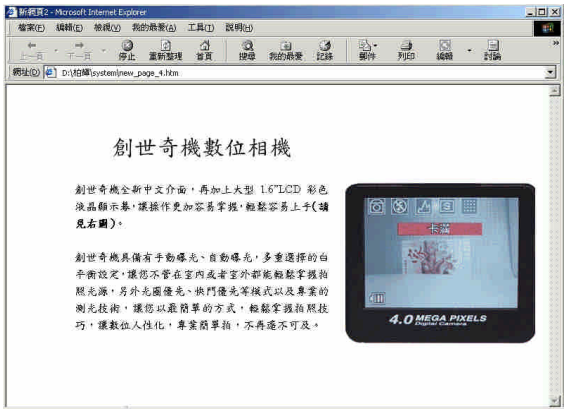

Figure 1. A snapshot of the animated display

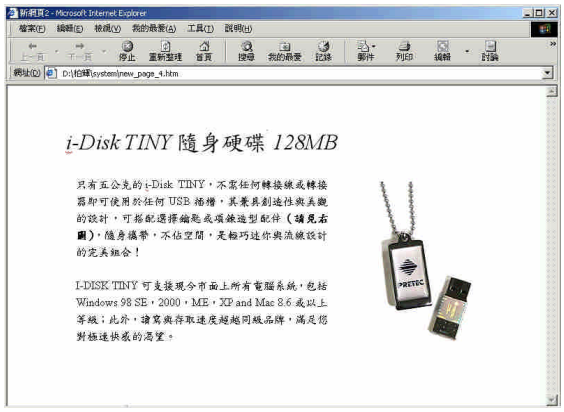

Figure 2. Product presentation with pictures

2.4. Procedures

The experiment was carried out at an ergonomics laboratory of a local university. Upon reporting to the lab, every subject received instructions with respect to how to operate the experimental system. Then, the subject was presented with the two topological E-malls that were labeled with A and B on a computer screen and was asked to click the labels in sequence to begin browsing the contents as long as he/she wished. The order of presenting the two different topological E-malls to each subject was randomized. Prior to the browsing stage, each subject was told that a retention test would be administered after the browsing session, in the hope that the subject would traverse the mall in as much detail as possible. After finishing the browsing task, the subject was offered a 15-minute break followed by the retention test. The test consisted of 30 recall questions where the subject was required to fill out one salient product feature in a blank. A computerized program was used to record the subject's traversing activities on the experimental E-malls so that the number of web pages repeatedly visited can be tallied.

3. RESULTS AND ANALYSIS

Table 1 shows the means of the two performance measures under the manipulation of the three factors. A mixed effect ANOVA was performed where the subject (i.e., the block variable) was considered as a random effect variable nested within the age group factor, whereas multimedia and web topology were both fixed effect variables. Accordingly, the variances from subjects nested within age groups (S(A)) served as the error term for the age effect. The variances from multimedia x S(A) served as the error term for the media effect and the age x media interaction. The variances from topology x S(A) served as the error term for the topological effect and the age x topology interaction.

Table 1. Means of retention accuracy (RA) and repeated page visits (RV) under the manipulation of age, display media, and web topology

	Young						Older					
	Hierarchical			Referential			Hierarchical			Referential		
	Animation	Picture	Text	Animation	Picture	Text	Animation	Picture	Text	Animation	Picture	Text
RA	0.62	0.64	0.45	0.51	0.46	0.38	0.42	0.38	0.22	0.38	0.38	0.16
RV	2.69	3.78	8.12	5.15	7.24	14.73	5.98	11.16	17.75	9.02	14.54	22.87

3.1 Retention Accuracy

The ANOVA results for the subject's performance in retention accuracy indicated that the three main effects were all significant. The age effect was apparent, with the older subject committing more errors in recalling product information than the younger subject ($F[1.,26]=25.19$, $p<0.0001$). The web topology also showed significant differences. The subject who browsed the hierarchical E-mall made fewer recall errors than those who browsed the referential counterpart ($F[1,26]=19.21$, $p<0.0002$). The presentation media also resulted in differentiated recall rate ($F[2,52]=7.44$, $p<0.0014$).

However, the significant main effects need to be further justified due to the existence of two significant interactions. First, the age x topology interaction was significant ($F[1,26]=6.60$, $p<0.02$). A simple-main-effect analysis revealed that the age differences for both of the hierarchical and the referential conditions contributed to the significance of the interaction. Specifically, when the product information was browsed on the referential E-mall, the older subject had a greater difficulty in correctly recalling the salient features than the younger subject (0.30 vs. 0.45, $F[1, 104]=43.84$, $p<0.0001$). Although the retention accuracy was improved for the older subjects when the E-mall structure was changed to a rigid organization, they still failed to reach the comparable level of recall accuracy as did the younger subject and the difference was significant (0.34 vs. 0.57, ($F[1, 104]=8.94$, $p<0.0035$).

Secondly, web topology also interacted with presentation media, regardless of which age group involved ($F[2,52]=4.58$, $p<0.01$). Further analysis of the interaction by the simple-main-effect method indicated that the significant differences between the two web structures mainly occurred at the treatment level of text-only presentation. Specifically, the hierarchical E-mall resulted in significantly higher recall rate than the referential E-mall only when the use of the former web structure was coupled with the display of text-only web contents (0.33 vs. 0.27, $F[1, 78]=25.95$, $p<0.0001$). However, when the presentation media was raised up to the static pictures and the animation levels, the differences in accuracy performance between the hierarchical and the referential web topology were merely due to a random chance.

3.2 Repeated Visits

The ANOVA results showed that the three main effects for the subject's performance in repeated visit of web pages were all significant. The age effect was significant and the older adults took longer distance to get back on correct tracks than did the young subjects. ($F[1,26]=23.96$, $p<0.0001$). The effect of web topology was also significant, with the number of repeated visits being reduced significantly when the E-mall browsed was switched from the hierarchical condition to the referential condition. ($F[1,26]=29.63$, $p<0.0001$). The

significant effect of presentation media showed that whether the product information was display by multimedia did count in assisting the subject in E-mall navigation ($F[2,52]=19.66$, $p<0.0001$).
Nevertheless, these results need to be further examined because both of the interactions of age x web topology ($F[1,26]=5.35$, $p<0.03$) and age x presentation media ($F[2,52]=5.98$, $p<0.005$) were significant. A simple-main-effect analysis for the age x web topology interaction indicated that the older adults tended to visit the same web page once more than did the younger subjects in spite the E-mall browsed offered a structured web contents (9.04 vs. 4.86, $F[1, 104]=9.76$, $p<0.002$) and the difference still stayed significant when the product information on the web was exhibited in a referential manner (15.48 vs. 11.63, $F[1,104]=28.38$, $p<0.0001$)
As far as the age x presentation media interaction was concerned, the simple-main-effect analysis indicated that which level of presentation channel was used to display the product information did matter. Specifically, the number of web pages that were repeatedly opened by the older subject was significantly larger than that by the younger subject when the E-mall displayed product information with text-only presentation (20.31 vs. 11.42, $F[1,78]=39.35$, $p<0.0001$). Although the age differences were reduced to some extent for the condition of static pictures, the age effect was still statistically significant (12.60 vs. 5.01, $F[1,78]=15.45$, $p<0.0002$). Nevertheless, when the animation was employed, the older subject was able to reach a similar level of navigation performance, evidenced by a simple-main-effect analysis that indicated the difference in the number of repeated visit of the web pages was only due to a chance result.

4. DISCUSSION

In general, the present study was in line with the existing ageing literature indicating that elderly people were at disadvantage in computer-based work. As shown by the above results, the older subjects were less capable of recalling the product features and were more likely to lose the whereabouts while shopping an E-mall web site. The interactions of the performances between the two age groups provided further implications for the design of an E-mall interface that is elderly-friendly.
We begin the discussion with the measure of repeated visits. An E-mall page that was repeatedly visited may imply a situation where the subject failed to find an exit for next navigation movements (i.e., disorientation). The age x topology interaction indicated that the older adults were unable to manage the relative layout of the product as compared to their younger counterpart and this was particularly true when the referential E-mall web was perused. According to the theory of spatial metaphor [Kim 95], the reason may be attributed to the inability of the older adults to develop an accurate and comprehensive cognitive map regarding the mall orientation, due to their declined spatial memory. With the help of the rigid parent-child links for the hierarchical E-mall, the construction of the mental map was offered a reference framework and therefore the disorientation phenomenon was reduced to some extent. It is thus suggested that a hypertext-based E-mall interface for the elderly should be designed towards the use of organized topology to help facilitate an associated cognitive product map. However, this implication does not mean we should use hierarchical topology whenever possible, but suggests incorporation of any portion a hierarchical component into the web would help for older shoppers to reduce disorientation. The rigid structure of a hierarchical web often results in the navigation moves too tedious after all.
The navigation performance between the two age groups can also be mediated by how the E-mall contents were displayed. The age x media interaction indicated that the disorientation

problem for the older adults can be relieved if the salient product features were exhibited via animation. The result pointed to some interesting implications concerning the use of multimedia for ageing. First, the dynamic characteristics underlying animated visuals may draw higher attention to the presented stimuli and the stronger motivation would in turn bring about greater mental efforts to result in deeper information processing. The enhanced memory of the product features makes it possible that the well-remembered information will act as landmarks that are crucial for developing an accurate cognitive map so that the subject will be better off in terms of knowing the whereabouts during the navigation process. Older adults can particularly benefit from the use of dynamic visuals as they are vulnerable to cognitive spatial manipulation and animation should receive higher weights in the design of ageing-friendly web pages accordingly. Secondly, Weiss [02] argued that based on the static pictures and animated visuals share the same coding foundation in terms of how long the stimuli can be retained. The result of present study was not consistent with this postulate nevertheless. The older subject who received static pictures associated with the product features was unable to improve their navigation performance to the level where animation was employed. The differentiated effect between static pictures and animated visuals leaves room for further examining the coding mechanisms underlying these two presentation channels. This is particularly important as animated display has increasingly been manifest nowadays.

As far as the recall performance was concerned, the age x topology interaction provide strong evidence that the elderly people are indeed unfavoured when it comes to retaining the information from web browsing. Even with the guidance of the organized navigation paths provided by the hierarchical E-mall, the older subject was still unable to reach the same retention level as with the young subject. It appears that the declined memory ability due to ageing may account for this inferior performance. It is also possible that the disorientation problem occurred during the navigation process interfered with how well the older adults can retain the product information. The additional efforts with which the older subjects require to clarify the web orientation make it more difficult for them to devote the already limited cognitive resources to the web contents. We should therefore be aware of the fact that the older adults are particularly vulnerable in recalling web contents and appropriate interface design considerations for the older people should be taken into account, such as a more hierarchical-oriented E-mall structure, and reduced web contents, etc.

Despite the topological impact with respect to the age factor, the effect of multimedia on E-mall retention was invariant across different age groups. Nevertheless, the presentation channel interacted with the type of web topology on which the subject performed the navigation task. As indicated by the result, the retention levels between the two web structures were different only when text-only contents were provided. However, when the product information was displayed with pictures-based presentations, either static or dynamic, the recall performance for the hierarchical web was as accurate as that for the referential web. The disorientation problem induced by the cross references of the network web is likely to interfere with the subjects' cognitive allocation and therefore jeopardize how well they can retain the product information. This interpretation justifies the interaction analysis for the text-only condition, but why the interfering impact on retention disappeared for the pictures-based presentation? It is possible that pictorial presentations result in deeper processing of the stimuli seen and this enhanced process overrides the interference effect on memory from the disorientation problem. It is therefore suggested that a virtual shopping environment should be designed with graphs, either in the form of static pictures or animated visuals, in the place of pure text presentation. The shoppers who have navigated such an E-mall can eventually remember the products exhibited to a maximum extent.

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