2002

Human-computer interaction in e-business

Hong-In Cheng
Iowa State University

INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps.

ProQuest Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600

Human-computer interaction in e-business

by

Hong-In Cheng

A dissertation submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Industrial Engineering

Program of Study Committee:
Patrick E. Patterson, Major Professor
Thomas Barta
S. Keith Adams
John Jackman
Judy M. Vance

Iowa State University

Ames, Iowa

2002

UMI Number: 3073438

UMI Microform 3073438

ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

Graduate College
Iowa State University

This is to certify that the doctoral dissertation of

Hong-In Cheng

has met the dissertation requirements of Iowa State University

Signature was redacted for privacy.

Major Professor

Signature was redacted for privacy.

For the Major Program

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1

CHAPTER 2

CHAPTER 4

CHAPTER 5

CHAPTER 6

LIST OF FIGURES

CHAPTER 1

CHAPTER 2

CHAPTER 3

CHAPTER 4

CHAPTER 5

CHAPTER 6

CHAPTER 1. GENERAL INTRODUCTION

HUMAN –COMPUTER INTERACTION

Definition

Human-Computer Interaction (HCI) is a design activity occurring when a human performs a task using a computer. The user interface is a channel where these two different systems communicate with each other. The interface must be carefully designed to allow successful communication, since humans and computers have very different methods of communication. The goal of HCI is to develop a useful and usable interface.

Brief History of HCI

In the initial stages of the computer age, humans communicated with computers using punch cards and the keyboard input introduced later. At this time, the dialog between human and computer was based on the computer's limitations. A primitive handheld pointing device was introduced in the 1960's and the ball mouse widely used today was patented in 1974 by Xerox. In 1980 the Xerox systems, Altus and STAR, introduced a new interaction technology-pointing and selecting with a mouse. However, Apple's Macintosh popularized these techniques in 1984. In 1989, UNIX-based GUIs were employed and Microsoft Windows 3.0 released. Microsoft Windows 3.1, 95, 98, NT, 2000, and XP were released one after another, with continuous development of the interface.

Screen design also has advanced greatly since a cathode ray tube display was first attached to a computer. A 1970's alphanumeric screen used complicated fields with often

cryptic and unintelligible captions (Galitz 2002). Tullis (1983) examined guidelines about overall density, local density, grouping, and layout complexity and suggested a method to measure the complexity of screen design. Screen designs became less cluttered through the application of guidelines like grouping and alignment of objects. The advent of the graphic interface opened a new era in the development of the user interface, utilizing, for example, cognitive models (Hornof and Kieras 1997 and Anderson et al. 1997), and design guides (Brown 1988 and Mayhew 1992).

The Internet became popular in the early 1990's and has brought many changes to our lives. It was the advent of the Internet that brought about the true beginning of the informational epoch. Interaction design on websites has become a significant issue because of the importance of Internet.

Usability

The International Organization for Standardization (ISO) defines usability as "the effectiveness, efficiency and satisfaction with which a specified set of users can achieve a specific set of tasks in a particular environment" (ISO 9241). Shneiderman (1992) introduced five user-oriented attributes of usability: learnability, efficiency, memorability, errors, and satisfaction.

Dix et al. (1998) suggested learnability, flexibility, and robustness as three main methods to support the usability of interaction design, with each of these principles including several sub-principles (Table 1.1).

Table 1.1. Principles of usability

	Main Principles		
	Learnability	Flexibility	Robustness
Sub-principles	Predictability	Dialog initiative	Observability
	Synthesizability	Multi-threading	Recoverability
	Familiarity	Task migratability	Responsiveness
	Generalizability	Substituitivity	Task conformance
	Consistency	Customizability	

Many different methods have been employed to evaluate usability. Cato (2001) tested usability with users, heuristic evaluation, and AUA (awareness, understanding, and action). Representative users participated in an experiment and evaluated usability by using either real or simulated interaction design, paper prototypes, or questionnaires. Analytical and empirical methods were also proposed by Rossen and Carroll (2002).

Standards and Guidelines

For developing a usable interaction design, user interaction standards and guidelines can be utilized. Designers need to interpret and adapt such standards to apply actual design because they are very general and simple. MIL-STD-1472c (1990) entitled "User-Computer Interface" is an example of a standard.

Many guidelines and studies related to guidelines for user interface design have been published in books (Brown 1988 and Mayhew 1992), articles (Reed et al. 1999 and Evans 2000), and web sites (Cuergo, http://ergo.human.cornell.edu/ahtutorials/interface.html, IBM's ease of use Websites, http://www-3.ibm.com/ibm/easy/eou_ext.nsf/publish/558, etc.). Guidelines usually provide principles applying to general interaction design, however, a general solution does not exist which is applicable to all situations. For that reason, independent study is required to produce a usable user interface. For example, Smith and Mosier (1986) collected 944 guidelines that include data entry, data display, sequence control, user guidance, data transaction, and data protection.

ELECTRONIC BUSINESS (E-BUSINESS)

Definition

E-commerce is the exchange of goods, services, information, and payments across an electronic network. OECD (1997) defined e-commerce as "all forms of commercial transactions involving both organizations and individuals, that are based upon the electronic processing and transaction of data, including text, sound, and visual image." The World Wide Web is especially being used for electronic transactions. Schneider and Perry (2000) formed a broader definition, "the user of electronic data transaction to implement or enhance any business process."

In the early 1990s, the Internet started began being used commercially, making e-commerce an important issue. E-commerce is first of all electronic commerce, but has a much broader connotation: the buying, selling, delivery of information, providing customer service, collaborating with other business, increasing productivity, etc. (Napier et al. 2001).

E-business is commonly thought to include these various activities. However, these two terms are usually considered to be synonymous. In this paper, e-commerce and e-business will refer to the same concept.

Incentives for E-commerce

Napier et al. (2001) indicated the many advantages of e-business for both sellers and buyers (Table 1.2). OECD (1997) also showed the advantages of e-commerce for transaction management and business efficiency.

Table 1.2. Advantages of e-business

Merchants	Buyers
Higher sales opportunity	Wider selection availability
Simple, quick, and cheap transaction	Simple, quick, and cheap transaction
No time limit of operation	Easier comparison of price and delivery
Access to global markets	Access to global markets

Website Design

Grose et al. (1998) demonstrated the differences between the design guides for web sites and those for traditional interfaces by examining 357 web sites design guides and 270 traditional interface design recommendations. Vora (1998) suggested a methodology, similar

to general system development, for designing web: planning, analysis, design and development, testing, implementation, and maintenance. Her methodology is summarized in the table 1.3.

Table 1.3. Web design methodology

Planning	Establishing the goals of a web site Understanding user needs and computing environments Identifying owner and author needs
Analysis	Analyzing content Analyzing process of interaction
Design and Development	Understanding user behavior Designing individual pages Utilizing advanced technology Designing for international users Keeping consistency
Usability Testing	Deciding scope of usability testing Conducting usability test
Implementation	Transferring files to web server
Maintenance	Updating web site content Checking web site integrity Monitoring trends Evaluating and implementing newer technology

The World Wide Web provides a hypertext system to support easy navigation for users within or between websites. Websites also contain various multimedia like graphics, sound, movies, etc. In addition, two-way interactive techniques made websites grow quickly and electronic transactions possible on the web. This dissertation deals with human-computer interactions on the Internet, especially as related to e-commerce website design.

Future of E-Business

OECD (1997) reported the quick establishment of e-business, predicting huge changes with business, society, and economy due to e-commerce, encouraging governments to consult with various participants, and pursued diverse and flexible strategies. Forrester Research predicted that $2.7 trillion in business would be transacted on the web by 2004 (Kurtzman et al. 2001).

It appears that at least for the foreseeable future, e-business will keep growing and new e-brands will appear continuously. Even though electronic commerce does not guarantee success, many companies will become wealthy using e-commerce.

DISSERTATION ORGANIZATION

This dissertation is devoted to human-computer interaction, usability, and e-business. Each chapter includes empirical studies to help understand human-computer interaction better and suggests a methodology to improve usability (Figure 1.1).

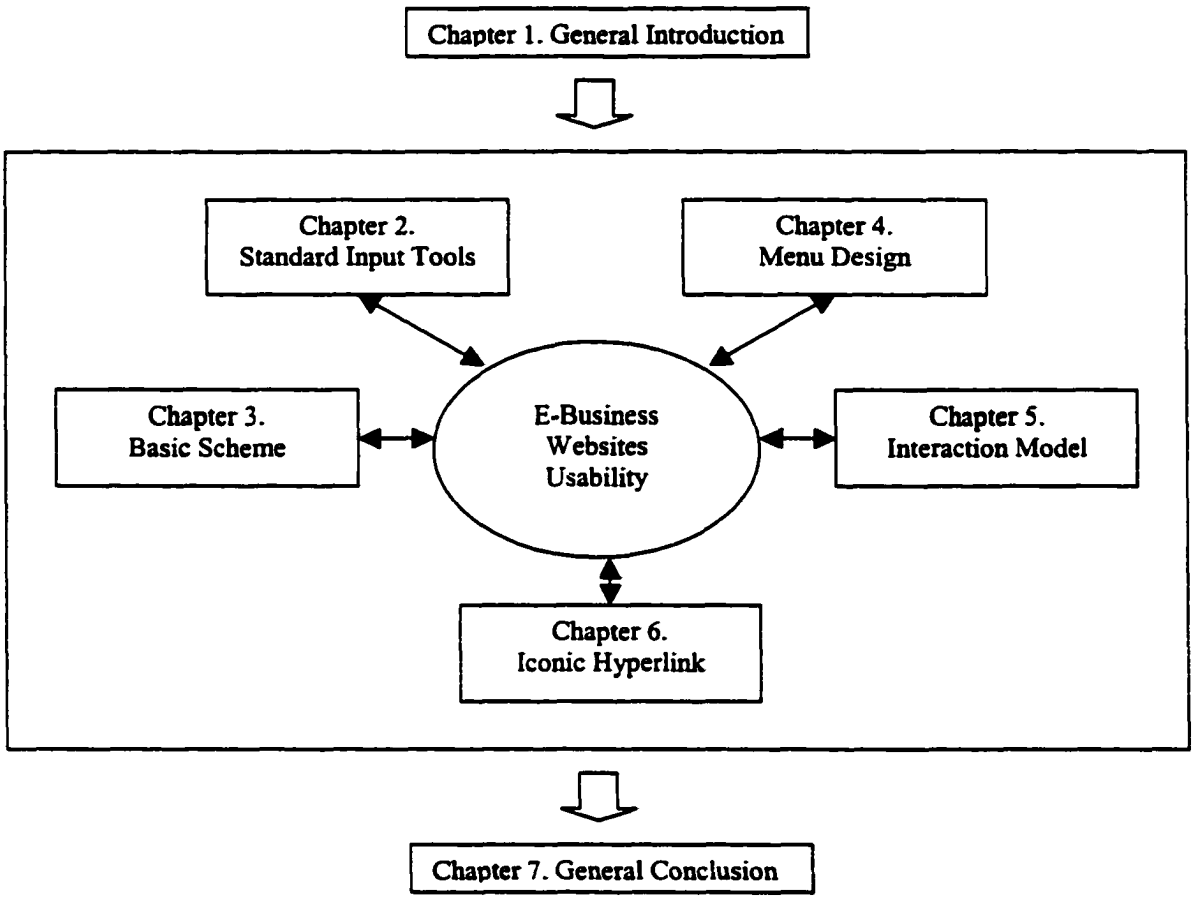


Figure 1.1. Organization of dissertation

Chapter two, entitled "Data Input Design on Hotel Reservation Web Sites", compared standard data input tools and found optimal input characteristics. Utilizing an existing standard interface makes web sites simpler and more usable (Somborg 2000), but data input type does not determine which input design should be used.

Chapter three, "Evaluation of E-Bookstore Characteristics", indicated problems of existing design guidelines and suggested more specific design guidelines for e-bookstores. Four simulated online bookstores were constructed based on the content analysis of several existing e-bookstores.

Chapter four, "The grid menu: efficient and robust selection of menu-items", evaluated potential ability of grid menu by comparing pull-down and fisheye menus. Performance time and usability factors were accessed for each menu containing 28 university courses, 50 states, and 100 web sites respectively.

Chapter five, "An interaction model for longer pull-down menus" proposed an interaction model including perception, cognition, and motor behavior characteristics with longer pull-down menus. Proportional selection time increase based on menu position, time decrease for bottom menu-items, and rapid mouse movement for edge target were mainly considered.

Chapter six, entitled as " Iconic hyperlink on e-commerce websites", examined visual icons being used on commercial web sites and showed that icons were carelessly designed and used on e-commerce web sites. Not all icons reduce system complexity and mental load.

REFERENCES

Anderson, J. R., Matessa, M., & Lebiere, C. (1997). ACT-R: A theory of higher level cognition and its relation to visual attention. *Human-Computer Interaction*, 12 (4), 439-462.

Brown, C. M. (1988). *Human-computer interface design guidelines*. Norwood, N.J.: Ablex Publication.

Cato, J. (2001). *User-centered web design*. Harlow, England: Addison-Wesley.

Dix, A., Finlay, J., Abowd, G., & Beale, R. (1998). *Human-Computer Interaction* (2nd ed.). New York: Prentice Hall.

Drury, C. G. (1995). Designing ergonomics studies and experiments. In Wilson, J. R. &

Corlett, E. N. (Ed.), *Evaluation of human work: a practical ergonomics methodology* (2nd ed.). Bristol, Pa.: Taylor & Francis.

Eberts, R. E. (1994). *User interface design*. New York: Prentice-Hall.

Evans, M. B. (2000). Challenges in developing research-based Web design guidelines. *IEEE Transactions on Professional Communication*, 43 (3), 302-312.

Galitz, W. O. (2002). *The essential guide to user interface design: An introduction to GUI design principles and techniques* (2nd ed.). New York: John Wiley.

Grose, E., Forsythe, C., & Ratner, J. (1998). Using web and traditional style guides to design web interfaces. In Forsythe, C., Grose, E., and Ratner, J. (Ed.), *Human factors and web development*. Mahwah, N.J.: Lawrence Erlbaum Associates.

Hornof, A. J., & Kieras, D. E. (1997). Cognitive modeling reveals menu search is both random and systematic, *Proceedings of CHI '97 Conference on Human Factors in Computing Systems*, 107-114. ACM, New York.

Kurtzman, J., & Rifkin, G. (2001). *Radical E: from GE to Enron*. New York: Wiley.

Mayhew, D. J. (1992). *Principles and guidelines in software user interface design*. New York: Prentice Hall.

Muller, M. J., McClard, A., Bell, B., Dooley, S., Meiskey, L., Meskill, J. A., Sparks, R., & Tellam, D. (1995). Validating an extension to participatory heuristic evaluation: quality of work and quality of work life. *Proceedings of CHI '95 Conference on Human Factors in Computing Systems*, 2, 115-116. ACM, New York.

OECD. (1997). *Electronic commerce: opportunities and challenges for government.*

Reed, P., Holdaway, K., Isensee, S., Buie, E., Fox, J., Williams, J., & Lund, A. (1999). User interface guidelines and standards: Progress, issues, and prospects. *Interacting with*

computers, 12 (2), 119-142.

Rosen, M. B., & Carroll, J. M. (2002). *Usability engineering: scenario-based development of human-computer interaction*. San Francisco: Morgan Kaufmann Publication.

Shneiderman, B. (1992). *Designing the user interface: strategies for effective human-computer interaction*. Reading, Mass.: Addison-Wesley.

Smith, S.L. & Mosier, J. N. (1986). *Guidelines for designing user interface software*. MITRE Corporation.

Somberg, B. J. (2000). Procedural consistency in the user interface, *Proceedings of the IEA 2000/HFES 2000 Congress*, 307-310. Human Factors and Ergonomics Society.

Tullis, T. S. (1983). The formatting of alphanumeric displays: a review and analysis. *Human Factors*, 25 (6), 657-682.

Vora, P. (1998). Human factors methodology for designing web sites. In Forsythe, C., Grose, E., and Ratner, J. (Ed.), *Human factors and web development* (pp. 153-172). Mahwah, N.J.: Lawrence Erlbaum Associates.

CHAPTER 2. DATA INPUT DESIGN ON HOTEL RESERVATION WEB SITES

A paper published in the proceedings of Hawaii International Conference on Business

Hong-In Cheng and Patrick E. Patterson

Abstract

The purpose of this study was to compare data input tools used in e-commerce applications on the web and find optimal input design characteristics. Basic data entry tools such as a pull down list, list, text input box, and radio box were examined by inputting information into a simulated hotel room reservation web site. Significant effects were obtained for data input time between the different input tools for arrival/departure date and room submission. The results indicated that a text input box was better than radio box, list, and pull down list regarding input performance time. However, the pull down list was considered by the subjects to be the most satisfactory, simplest, and easiest to remember its usage across data entry types. A simple list was determined to be the best for the input of binary data.

INTRODUCTION

Early web sites were designed to display textual information with hyperlinks that allowed the user to navigate the Internet. Ease of publishing/updating with web sites, low cost of having web sites, and the introduction of multimedia and interactive techniques have triggered the explosive development of the web (Vora 1998). Advanced techniques have

made it possible to build two-way interactive web sites, resulting in the birth of e-commerce on the web. These conveniences also are responsible for inducing poor web sites and creating usability problems (Comber 1995). The International Organization for Standardization (ISO) defines usability as "the effectiveness, efficiency and satisfaction with which a specified set of users can achieve a specific set of tasks in a particular environment". Web site usability issues are discussed in detail by Dix et al (1998), Keevil (1998), and Spool et al. (1997).

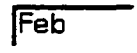
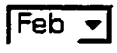
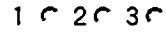
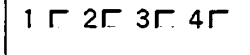
Interface design is very important in the building of usable interactive web sites. Well-designed interfaces attract people to a web site as compared to poorly designed interfaces web sites, which often perish. A simple and useful method to design usable interactive web sites is by the use of existing interface standards (Somborg 2000).

The hypertext markup language (HTML) is used to design the user's data entry interface on the web, and supports several standard data input tools such as text input box, pull down list, list, radio box, check box, and so on (Table 2.1). Users can submit what they want on the web by typing in a blank box with a text input box, clicking downward arrow and selecting an option with a pull down list, and scrolling up and down and selecting with a list. Radio box allows users to select just one option but a check box supports multiple choices.

Data input type does not determine which input tool should be employed. For example, the arrival and departure date for a hotel reservation can be selected by pull down list, list, or text input box. However, little information exists regarding which standard data input tool is more usable when using an e-commerce site. The purpose of this study was to

determine whether an effective usage pattern exists for the basic data input tools through use of a simulated web site designed for hotel room reservations.

Table 2.1. Standard data input tools

Text input box	Pull down list	List	Radio box	Check box
				

METHOD

Subjects

Thirty students (20 male, 10 female) from an introductory ergonomics class at Iowa State University participated in the study and received extra class credit. The subjects ranged in age from 19 to 50 (mean=22.3, SD=6.035). Thirteen subjects reported having prior experience in reserving a hotel room on the web. Twenty-nine subjects used the web daily.

Interface

A simulated web site developed for the hotel reservation service consisted of a brief description page, a set of user's data input pages, and a number of questionnaires. Required user inputs were date input, number input, binary selection (smoking, nonsmoking), and multiple choices (room type). Pull down list, list, and text input box were employed for the arrival and departure date input, because of the large number of potential choices available to

the user and the familiar options. Four different standard input interfaces, pull down list, list, text input box, and radio box, were used for number input such as number of adults, children, and rooms. Smoking preference and room type were designed to be selected by use of pull down list, list, and radio box.

Experimental Design

The experiment was designed as a within subject design. The independent variables were the data entry tools and the dependent variables were data input time, satisfaction, simplicity, flexibility, and the degree of ease in remembering the usage of the input tool. Time was used as a performance variable in the experiment. Error was not considered because typical customers hardly make mistakes when reserving a hotel room on the web and enough information was given to subjects to prevent their errors.

A Java Script program was developed to measure time from loading a web page to the subject clicking a submit button. Answers for questionnaires were stored on the web by Active Server Page (ASP).

The experiment approximately took 10 minutes to complete. Each participant submitted date input three times, number input four times, smoking preference input three times, and room type input three times using different data input tools to reserve a hotel room on the web as well as answering questionnaires for each set of data input. For each data input, the order in which the web pages were shown to the subjects was random.

The questionnaire asked eight questions about usability at the end of each set of data input (Table 2.2). Pictures of interface designs were given with questions on the web page. The participants ranked the data input tools.

Table 2.2. Usability questions

Category	Questions
Satisfaction	Which web page format are you most satisfied with?
	Which web page format are you most dissatisfied with?
Simplicity	Which web page format is simplest to use?
	Which web page format is hardest to use?
Flexibility	Which web page format is most flexible?
	Which web page format is most inflexible?
Ease of Recall	Which web page format is easiest to remember how to use?
	Which web page format is hardest to remember how to use?

Procedure

The introductory web page for general data input, such as gender, age, experience in making on-line hotel room reservations, and frequency of web usage, was first presented to each participant. Subjects were then given the scenario for the hotel room reservation.

After a practice run of the trial web page, participants were asked to submit their arrival date, departure date, number of adults, children, and rooms, smoking preference, and room type as quick as possible. Before starting each set of data inputs, related parts of the scenario were given again to improve the user's memory, as typical customers are familiar enough with their reservation needs so they seldom make mistakes. A questionnaire was

presented to participants after they completed each set of requested inputs. Figure 2.1 illustrates the procedures of the experiment.

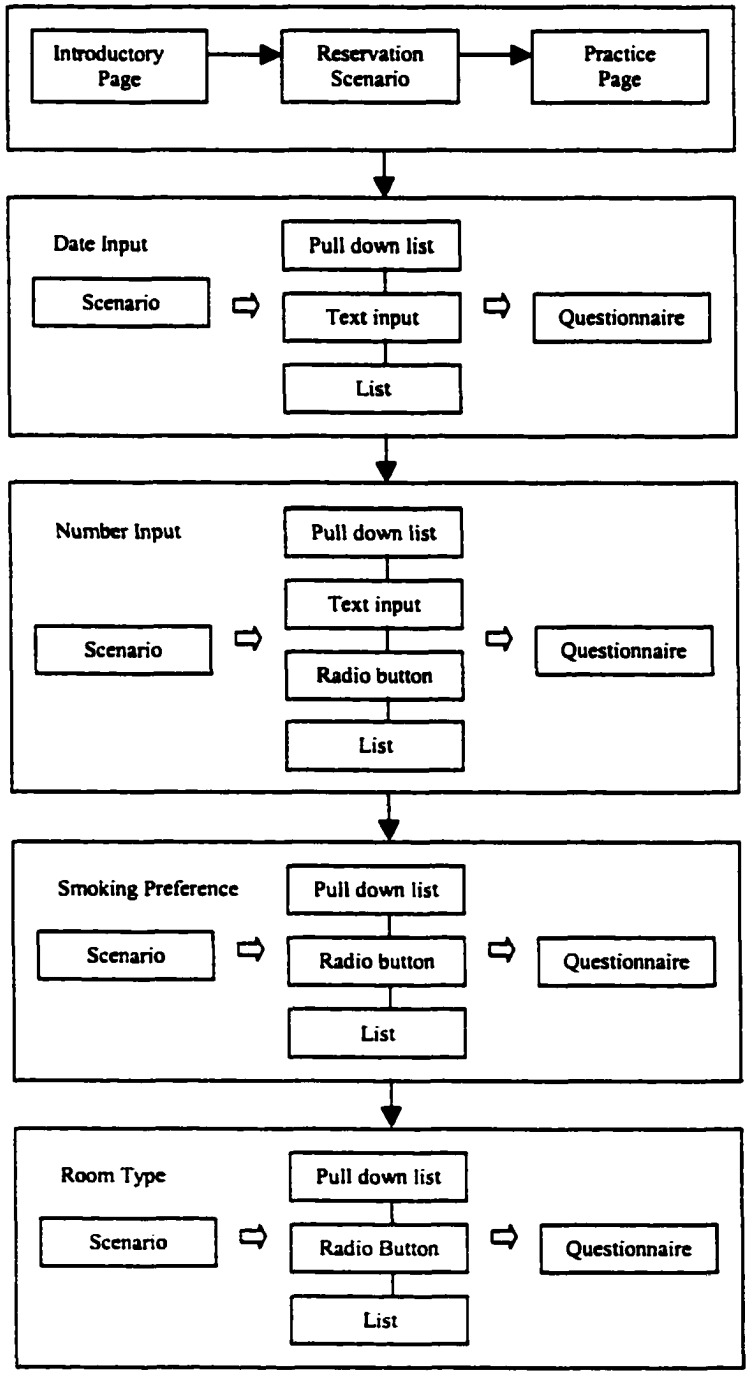


Figure 2.1. Procedure of the experiment

RESULTS

Thirty subjects completed the experiment; one participant's data were not retrieved for the smoking preference and room type input. Table 2.3 shows the mean and standard deviation of data input times.

Table 2.3. Data input time due to the input design (unit: seconds)

	Date			Number				Smoking Preference			Room type		
	PD	TI	L	PD	TI	RB	CB	PD	RB	L	PD	RB	L
Mean	14.998	11.874	16.398	6.263	5.418	6.051	4.817	2.619	2.818	2.386	6.431	3.487	2.659
SD	9.919	4.819	13.239	5.795	2.549	2.128	1.527	1.617	2.612	1.080	1.379	2.364	1.137
n	30	30	30	30	30	30	30	29	29	29	29	29	29

PD: pull down list, TI: text input box, L: list, RB: radio box, CB: check box

The experimental errors are assumed independently distributed in the normal distribution for the analysis of variance. There were significant differences among data input times due to the input entry designs for arrival and departure date input $F(2,87) = 1.63$, $p<0.2$. By the least significant difference (LSD) method, it can be concluded that text input box needs significantly less time to input the date than pull down list and list (LSD=1.74). Significant effects were obtained for satisfaction $F(2,87)=3.84$, $p <0.03$, simplicity $F(2,87)=5.01$, $p <0.009$, and degree of ease to remember the usage $F(2,87)=4.19$, $p <0.02$ for the date input. Pull down list was significantly better than list and text input box for these factors.

Significant effects were found for satisfaction $F(2,84)=6.25$, $p<0.003$, simplicity $F(2,84)=9.19$, $p<0.0003$, flexibility $F(2,84)=3.99$, $p<0.03$, and the degree of ease to remember the usage $F(2,84)=9.19$, $p<0.0003$, for the smoking preference input. A list was referred for satisfaction, simplicity, and flexibility. For the ease of usage memory, radio box was considered best.

For the room type input time, radio box and list are significantly better than pull down list $F(2,84)=1.74$, $p<0.18$, $LSD=2.68$. Subjects assessed pull down list significantly better than radio box and list in simplicity $F(2,84)=17.16$, $p<0.0001$, and the degree of ease to remember the usage $F(2,84)=14.79$, $p<0.0001$.

DISCUSSION

Usually customers need to change the displayed day or month to submit their arrival and departure date on the web page because the current date is normally displayed. As the results show, users need the least amount of time using a text input box when submitting date information. However, subjects thought the pull down list is the most satisfactory, simplest, and easiest to remember the usage. When designing a web page containing date input, there might be the trade-off between text input box and pull down list. If a user is an expert and input time is critical, using a text input box would be optimal otherwise pull down list will be a good design. Currently forty-five web sites for hotel reservation were randomly selected from Yahoo search results and examined. These included fifteen American, ten French, ten Canadian, and ten German web sites. Their usage of the interface input tools were summarized in the Figure 2.2. Most web sites were using pull down list as a data input tools

regardless input type. Room type and Smoking preference input was not allowed on many web sites.

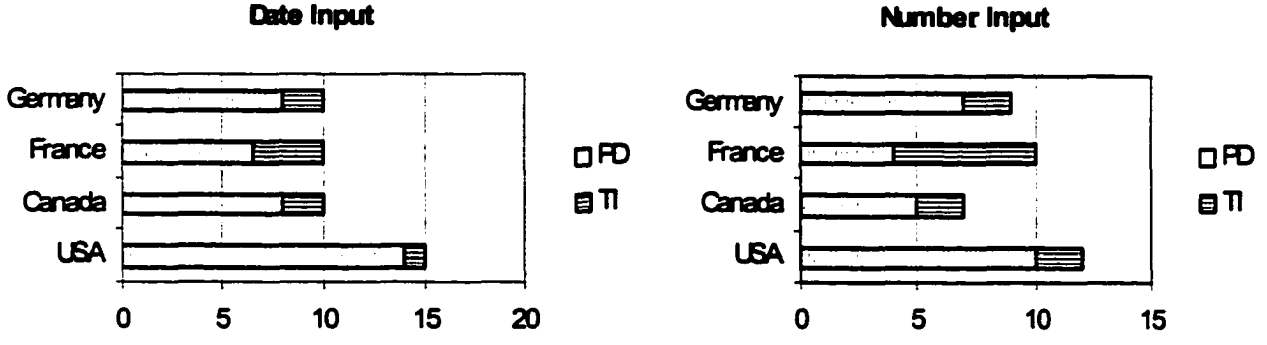


Figure 2.2. Interface tool usage

The results indicate list and radio boxes are better input tools when the selection is binary such as smoking preference. Subjects answered that a list is simpler, flexible, and more satisfactory. A pull down list requires clicking the downward arrow and selecting an option. On the other hand, a list needs scrolling up/down moving bar and choosing an option. We conclude people feel scrolling is more usable than clicking when making a binary selection. In addition, it appears that a pull down list and a list do not differentiate between selected and unselected options for binary selection. If enough space is available, a list is preferred for data entry with binary answers.

When the number of options to be selected is limited, such as room type decision, users thought a pull down list is simpler and easier to remember its usage. However a radio box and a list can save data input time.

With the increasing emphasis on e-commerce, it is important that the web design used provides an interface that both reduces the chance for input time/error and is user friendly. This study suggested several guidelines to design an interface on such web sites.

REFERENCES

Comber, T. (1995). Building usable web pages: An HCI perspective. *Proceedings of the First Austrian www Conference*. http://www.scu.edu.au/sponsored/ausweb/ausweb95/papers/hypertext/comber.

Dix, A., Finlay, J., Abowd, G., & Beale, R. (1998). *Human-Computer Interaction* (2nd ed.). New York: Prentice Hall.

Keevil, B. (1998). Measuring the usability index of your web site. *Proceedings of the ACM SIGDOC*, 271–277.

Somberg, B. J. (2000). Procedural consistency in the user interface. *Proceedings of the IEA 2000/HFES 2000 Congress*, 307-310.

Spool, J. M., Scanlon, T., Schroeder, W., & Snyder, C. (1997). *Web site usability: A designer's guide*. San Francisco: Morgan Kaufmann Publishers

Vora, P. (1998). Human factors methodology for designing web sites. In Forsythe, C., Grose, E., and Ratner, J. (Ed.), *Human factors and web development* (pp 153-172). Mahwah, N.J.: Lawrence Erlbaum Associates

CHAPTER 3. EVALUATION OF E-BOOKSTORE CHARACTERISTICS

A paper accepted at The Economics and International Business Research Conference

Hong-In Cheng and Patrick E. Patterson

Abstract

As a usable web site is essential for today's successful e-business, e-commerce web site design has been actively studied, resulting in a number of design guides being produced. However, as these guides do not provide specific design methodology, web designers still need their experience and intuition to build a web site. In this study, four simulated online bookstores were designed based on the content analysis of several existing e-bookstores. Customers' preference and effects of the usage of design items were investigated. Seventy-five percent of participants reported they would buy textbooks online even if there were no monetary benefit, but sixty-nine percent thought sale price is still most important for book purchases. E-brand and the duration of delivery were considered significant, similar to the brick-and-mortar marketplace. Search engine characteristics affect the ease of use of a web site and should be designed to be easily located on the screen. A web store was considered to be well-organized if its screen design presentation was columnar.

INTRODUCTION

The history of commerce, the exchange of goods or services, goes back thousands of years. There has been a tremendous change recently in commerce with the advent of the Internet and web. The new electronic business transaction, e-business, has become a part of our daily life and is still rapidly growing. Forrester Research predicted that $2.7 trillion in business would be transacted on the web by 2004 (Kurtzman et al. 2001).

There are a huge number of companies selling products, information, and service using e-commerce, but not every company makes a profit in the electronic marketplace. The web site is an essential component for successful e-business. Lohse and Spiller (1998) reported that web design influences e-business traffic and sales. Usable web sites promote prosperous e-business but poor design has an adverse affect on sales.

E-commerce web site design has been studied and several guidelines have been suggested: Easy and convenient to use, informative, speedy, secure web sites (Helander 2000 and Zilliox 2001). Efficient locations of general web objects were even studied to improve the usability of web sites (Bernard 2001). It is also known that the site structure must be designed carefully, web design should be consistent and attractive, the information or message must be delivered quickly without distracting customers, and planned goals and objectives must be achieved through the web sites (Napier et al 2001).

Web designers typically refer to style guides and then rely on their experience or intuition to build appealing commercial web sites. Usable web sites induce customers to make purchase decisions: visit, search, purchase, and payment (Helander 2000). However additional study is needed to determine which design factors make web sites usable. Web

designers need more specific information regarding how to build easy, informative and secure web sites. This study discovered several hints leading better usage of web sites items.

METHOD

Subjects

Forty-two Iowa State University students (27 male, 14 female) participated in the study and received extra class credit. The subjects ranged in age from 19 to 27 (mean=21.05, SD=1.56). Eighty six percent of subjects reported having prior experience in buying textbooks on an e-bookstore and twenty one percent of students indicated they always search for textbooks and compare prices on the web before any text purchase.

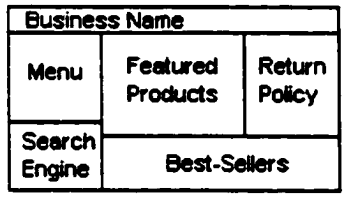
Interfaces

Several online bookstore web sites were downloaded and analyzed to serve as basis for simulating e-bookstore web sites. Four real e-bookstore web sites were modified little based on a contents analysis and were consistent by showing e-business name, trademark, navigation element, and contact information on every web page (Napier et al 2001).

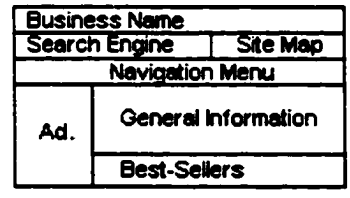
The first e-bookstore homepage used in this study sells books, movies, and video games and had a three-column style, navigation left (books, movies, video games, search engine), return policy right, feature products in the middle, and best-seller at the bottom (Figure 3.1. a). The second had a two-column style, two-layer navigation top (1^{st}: search engine, site map, 2^{nd}: shipping, shopping cart, help, contact information), advertisement left, and general and best-sellers information in the middle (Figure 3.1. b). To prove the security of the transaction, secured web site image was inserted in the first and second web sites. The

third web page had three columns, two-layer navigation top (search engine, books, magazines, hard to find, bargains), advertisement left, best-sellers information right, and general saving and web site information in the middle (Figure 3.1. c). The fourth homepage was designed to sell books, movies, software, and computers and had three-column style, two-layer navigation top (1st:view cart, account, 2nd: Books, movies, software, computer), search engine and menu left, new release right, and advertisement in the middle (Figure 3.1 d).

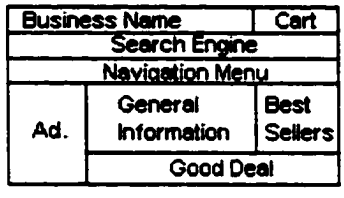
The structure of the second web site required three steps (clicks) to check out an item with the other web sites needing three or more mouse clicks (Figure 3.2).



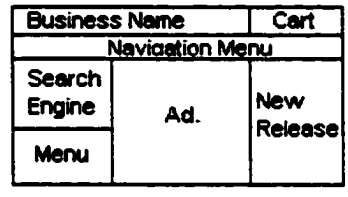
a) First website



b) Second website

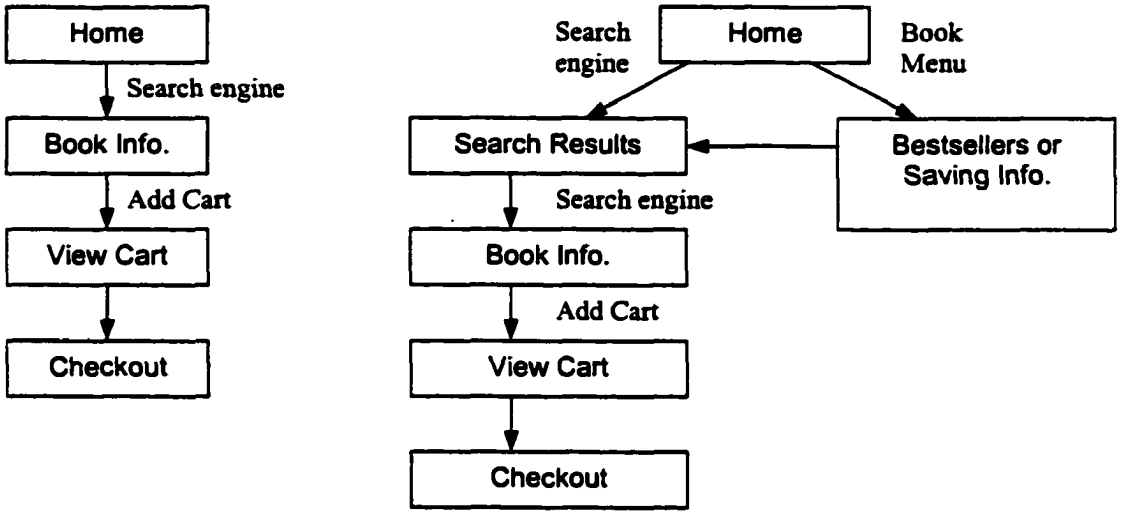


c) Third website



d) Fourth website

Figure 3.1. Home page designs of simulating web sites



a) Structure of second web sites b) Structure of first, third, and forth web sites

Figure 3.2. Structure of web sites

Procedure

Purpose, procedure, risks, and benefits of the experiments were explained to the subjects and informed consent was obtained. General questions were then asked about their purchasing experience and tendencies on the web. Subjects were then shown a textbook to buy on the web sites and given related information like author, publisher, publishing date, and retail price as textbook usually introduced in the first class.

The four web sites were examined in random order. Participants were asked to buy the book on the simulated web sites. After the simulated purchase, participants were given a questionnaire about their preference and the usability of web sites.

RESULTS

Sixty nine percent of subjects reported that the price was most important when they bought textbooks on the web sites and believed most web sites would be secure and reliable. Quick delivery (15%) and reputation of the web sites (10%) were also considered as important factors (Figure 3.3). A Chi-square test was employed to test significance. ($q=47.25 > 13.28=\chi^2_{0.01}(3)$).

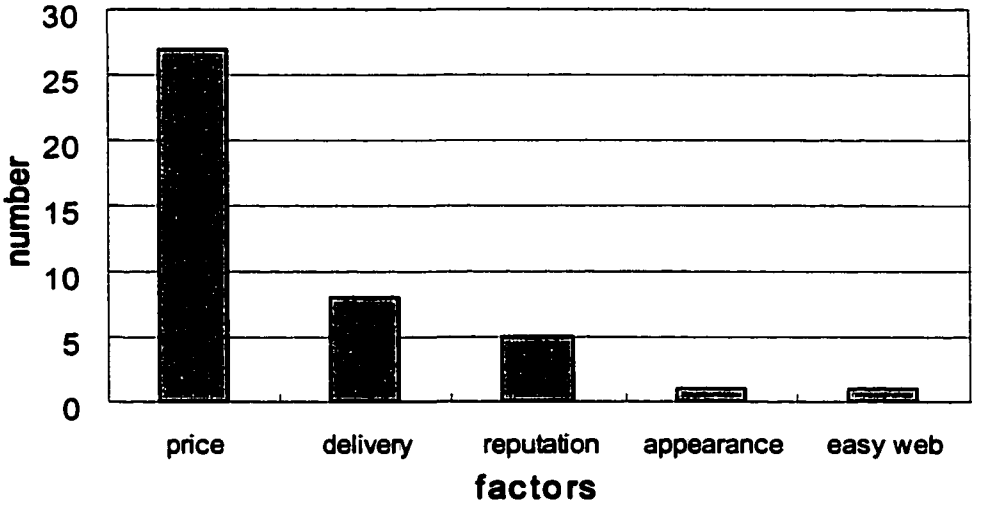


Figure 3.3. Important factors for online purchase

Subjects answered they would select well-known e-business (50%) and quick delivery (27%) if there is no difference in the price among e-bookstores. Participants expected a price discount on the web (mean=10.48% SD=8.09). However seventy five percent of participants reported they would buy the book on the web even though there was no monetary profit compared to brick-and-mortar bookstores. Fifty two percent of subjects replied web design could affect their purchase.

The first and fourth web sites were evaluated as being easier to use because of the ease of finding the book ($q=8.95 > 7.815=\chi^2_{0.05}(3)$, Figure 3.4). Subjects considered ease to finding a book, appearance, overall organization, and visual attractiveness when indicating their choice of best web sites. Discernible search engines were easily found and evaluated as easy to use.

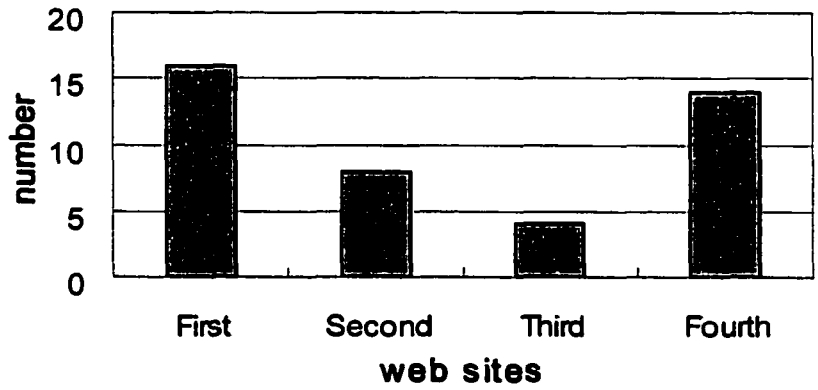


Figure 3.4. Best web site

Price comparison with other web sites, various delivery option, picture of items, and general information was assessed to make web sites informative. However no significant result was detected in the informative web sites evaluation.

Clearly divided column styles were considered to be well organized. Subjects considered the fourth web site is better organized than the others ($q=17.43 > 11.34=\chi^2_{0.01}(3)$, Figure 3.5).

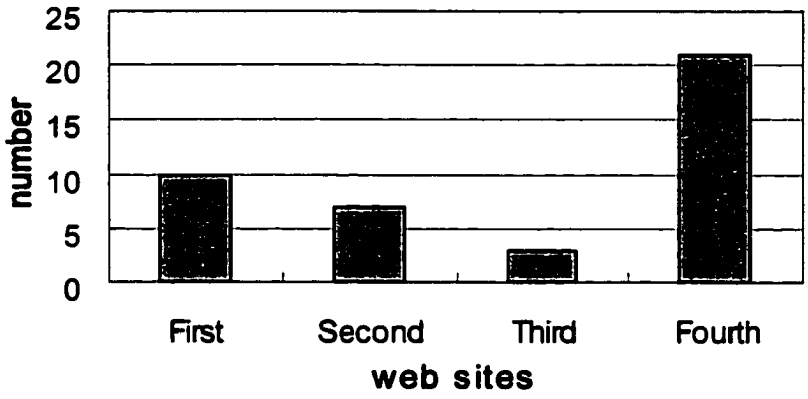


Figure 3.5. Website organization

There was no significant difference in the worst web site evaluation. Subjects rated web sites as poor when they were hard to navigate, time consuming, boring, too busy, less informative, and badly organized.

DISCUSSION

E-business is very similar to brick-and-mortar business. An attractive store will be heavily visited by customers but competitive price is very important. Although many students are willing to buy textbooks online without monetary benefit, a cheaper sales price is always a significant factor. Customers can easily find the cheapest web site using a price-comparing web site program.

E-brands and their reputations also affect customers' purchase just like typical business. It explains the reason of success of the large companies in the e-business in spite of their late launch dates. New and small e-business should try to make its brand name familiar to customers.

Subjects preferred quick shipping and handling since students typically need books delivered in a short time. For that reason several shipping options should be possible at e-bookstore. Of course improvement of overall handling process is also important.

E-business web sites should make it easy to find an item. Usually a search engine is provided for easy shopping similar to store clerk help you to find items at brick-and-mortar store. The search engine should be located and designed to be easy to find and use. Bernard (2001) showed that the middle section of a site's upper half is a good location for an internal search engine. However, in this study participants did not judge it easier to find a book with a properly located search engine because its background was same as the e-business brand location and so was hard to distinguish.

Subjects felt the online store was well organized when a single and clear column design was employed. Designers must structure their web sites simply because complicated column design gives customers a confusing impression. Web designers thus face the difficulty in deciding the degree of descriptive information and simplicity. Through this study simplicity seems to be more important than providing information.

Customers did not recognize the slight difference in shopping steps. Web design guidelines suggest using a three or four click purchase system. If this criterion is satisfied, shopping step does not influence purchase. Most customers believe online purchase is reliable whether a security warning was inserted or not.

REFERENCES

Bernald, M. L. (2001). Developing schemas for the location of common web objects. *Proceedings of the Human Factors and Ergonomics Society 45th Annual meeting*, 1161-1165. Human Factors and Ergonomics Society.

Cato, J. (2001). *User-centered web design*. Harlow, England: Addison-Wesley.

Helander, M. G. (2000) Theories and models of electronic commerce, *Proceedings of the IEA 2000/HFES 2000 Congress*, 2, 770-773.

Kurtzman, J. & Rifkin, G. (2001). *Radical E: from GE to Enron*. New York: Wiley.

Lohse, G. L. & Spiller, P. (1998). Quantifying the effect of user interface design features on cyberstore traffic and sales *Proceedings of CHI '98 Conference on Human Factors in Computing Systems*, 211-218, ACM, New York.

Napier, H. A., Judd, P. J., Rivers, O. N., & Wagner, S. W. (2001). *Creating a winning E-business*. United Kingdom: Course Technology.

Zilliox, D. (2001). *The get-started guide to e-commerce: getting online, creating successful Web sites, order fulfillment, getting noticed*. SMW Production.

CHAPTER 4. THE GRID MENU: EFFICIENT AND ROBUST SELECTION OF MENU-ITEMS

A paper published in the proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting

Hong-In Cheng and Patrick E. Patterson

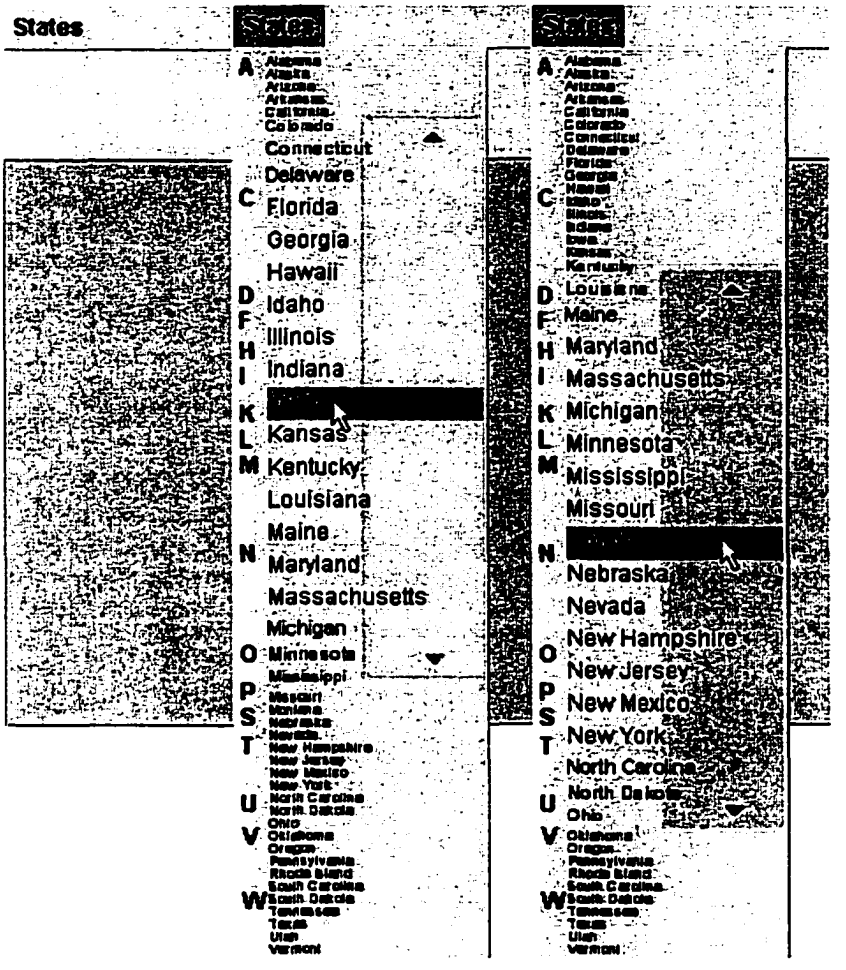
Abstract

With the increasing use of e-business web sites, users are often asked to select a menu-item from a large numbers of options. In this research, the pull-down menu, fisheye menu and grid menu were tested to compare the performance time, error rate, user satisfaction, simplicity, user friendliness, usefulness, and overall user preference of each menu type. The grid menu was more efficient in selection speed than the pull-down and fisheye menus when the number of menu-items was 50 and 100. The time needed to choose a menu-item with a grid menu was less affected by the size of menu and the physical location of an item within a menu. The pull-down and the grid menus were considered to be more satisfactory, simple, user friendly, and useful than the fisheye menu. 42.3 percent of subjects indicated that the grid menu was their preferred selection tool among the menus. The grid menu is an efficient and robust alternative menu choice for small and middle size menu lists.

INTRODUCTION

Clicking on a specific menu-item from a list has become important with the increasing use of e-business. In addition, large numbers of menu-items are frequently contained in web menus. One of the most often found menu styles is the pull-down menu; interactions between users and pull-down menus were studied by Byrne et al. (1999), Perlman (1984), and Walker et al. (1991).

The fisheye menu was introduced to select a menu-item more efficiently from a long list of possible choices (Furnas, 1986) and was compared with the more common menus by Bederson (2000). Fisheye menus magnify the font size of options close to the cursor and diminish the remainder by focus changing. One problem with the fisheye is this sensitive focus changing due to mouse movement. Focus lock mode was developed to solve the focus problem (Bederson, 2000). By moving the cursor to the right side of the menu, the right side becomes highlighted and focus lock mode activated (Figure 4.1). Thus, the focus is fixed regardless of the mouse movement, but the menu can be expanded and a menu-item can be selected in this mode. Focus lock mode is released, allowing the menu to return to the original configuration, when the cursor is moved back to the left side. Bederson (2000) reported that the fisheye menu was preferred by users and can save time. However, for menus having 2 ~ 30 options, the format of the fisheye is actually the same as the pull-down menu except for the addition of an alphabetical index. Additionally, if all options begin with the same letter, like the university course numbers in a department catalog (for example, IE department courses only have an "I" index), an index does not help users to select a menu-item efficiently.



a) Menu title b) Plain mode c) Focus lock mode

Figure 4.1. Fisheye menu for state selection

The grid menu is an alternative menu style for small and middle size menu-items. We defined a small menu as having 2 to 30 options, a middle menu having 31 to 100 items, and a large menu as having more than 100 menu-items. If screen space is not a problem, options can be spread over the screen allowing users to access a menu-item without dragging and scrolling down (Figure 4.2).

Alabama	Hawaii	Massachusetts	New Mexico	South Dakota
Alaska	Idaho	Michigan	New York	Tennessee
Arizona	Illinois	Minnesota	North Carolina	Texas
Arkansas	Indiana	Mississippi	North Dakota	Utah
California	[redacted]	Missouri	Ohio	Vermont
Colorado	Kansas	Montana	Oklahoma	Virginia
Connecticut	Kentucky	Nebraska	Oregon	Washington
Delaware	Louisiana	Nevada	Pennsylvania	West Virginia
Florida	Maine	New Hampshire	Rhode Island	Wisconsin
Georgia	Maryland	New Jersey	South Carolina	Wyoming

Figure 4.2. Grid menu for fifty states menu-item

The purpose of this study was to investigate the potential efficiency of the grid menu by comparison with pull-down and fisheye menus for a variety of menu selection item lengths.

METHOD

Subjects

Fifty-two subjects (33 male, 19 female) from an introductory ergonomic class at Iowa State University participated in the study and received extra class credit. The subjects' age ranges from 19 to 39 (mean=21.2, SD=3.16). Ninety six percent of subjects indicated they used the Internet everyday and had experience selecting an option from a menu having a long list of possible selections.

Materials

A fisheye applet was downloaded from "http://www.cs.umd.edu/hcil/fisheyemenu" and modified. Code was added to allow measurement of performance times and some lines of program were eliminated to delete unnecessary menus and focus length selection for the experiment. Focus length was fixed at 11 items and only the menu title was shown on the menu bar (Figure 4.1).

Three different applets were then designed for each menu. The first menu was for the selection of 28 IE department undergraduate courses at Iowa State University, the second consisted of 50 states, and the last contained the 100 websites used by Bederson (2000).

The grid menu was programmed using Java2 for the three menu selection.

Experimental Design

The experiment was completely randomized three-factor (3^3) within subject factorial design with unbalanced replication. Menu type, option length, and position were independent variables. Performance time, error, satisfaction, simplicity, user friendliness, and usefulness were the dependent variables. A 5-point Likert scale was used to obtain scores of satisfaction, simplicity, user friendliness, and usefulness. Performance time and the number of errors were measured using the JAVA applet.

Procedure

The participants selected an experimental sheet and filled out personal information before the experiment. The experimental sheet was composed of four sections: 1) name, age, gender, and Internet experience, 2) usability questions, 3) three randomly pre-selected

specific menu-items for each menu, 4) records of the response times.

Each subject was given a brief explanation of the experiment and was shown all nine web sites (3 menu-types × 3 menu items). The subjects were given a short time to examine the menus and the organization of the menu-items for all menus. The participants for each menu also chose four or five randomly selected trial menu-items during which the mechanism of performance measurement and the function of the focus lock mode in the fisheye menu were explained. When they felt comfortable with the menus and the environment, actual options were given to the subjects as specified on the experimental sheet they had selected.

The participants were instructed as to how they could complete the experiment and what we would be able to explain or show them during the course of the experiment. The randomly selected first web page was shown by clicking the hyper linked number below the menu applet, after which the subject checked the predetermined menu-item for that web page. The subjects reviewed their selection item for that menu before they actually performed the experiment to eliminate memory load as a factor. The participants continued selecting until the correct option was selected. Each subject was required to select the options twice for each menu in random order.

After completing all menus, subjects then checked the satisfaction, simplicity, user friendliness, and usefulness of each of the menus on a Likert 5-point scale. Finally, they were asked how often they used the Internet and which of the menus they preferred and why.

RESULTS

Performance Measurement

It took approximately 15 minutes for each participant to complete the experiment resulting in 936 performance data (52 subjects × 3 menus × 3 menu-items × 2 repetitions).

The performance time due to the menu type and option length are given in the Table 4.1. Performance time was linearly proportional to the length of the menu (Figure 4.3). This is consistent with the results of Byrne (1999) and Perlman (1984). An important observation is that slope of performance time varied with menu type.

Table 4.1. Performance time (ms) due to the menu type and menu-items (mean, SD)

Menu Contents	Pull-down	Fisheye	Grid
28 IE Courses	1809.21 (592.85)	1866.70 (850.97)	2070.09 (881.34)
50 States	2619.27 (1243.96)	3094.64 (1319.41)	2085.92 (733.96)
100 Web sites	4059.71 (1962.61)	5200.56 (2944.17)	2541.40 (848.41)

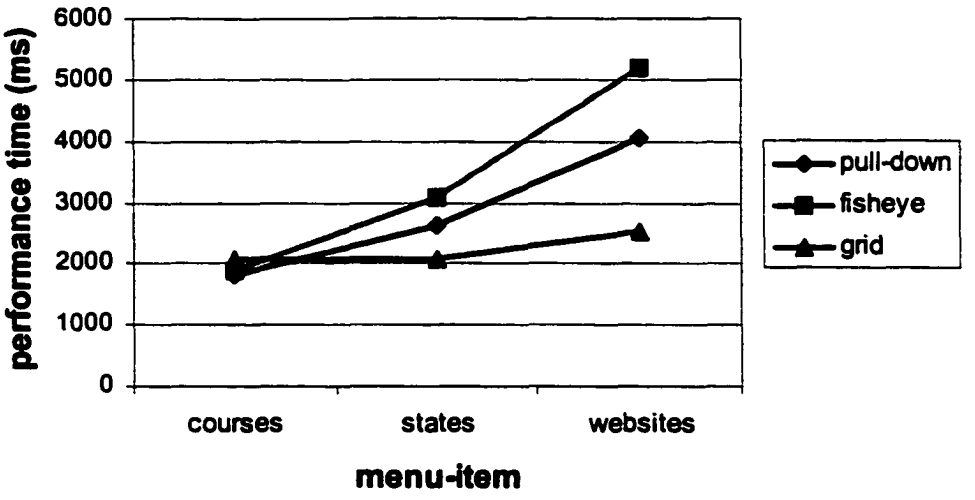


Figure 4.3. Performance Time

The experimental errors are assumed independently distributed in the normal distribution for the analysis of variance. Significant interaction was detected between menu type and the length of the menu-items. Regardless of menu type, less time was needed to select a correct option with shorter list. Furthermore the main effects of menu type ($F_{2, 909}=57.27$, $p<0.0001$) and menu length ($F_{2, 909}=175.96$, $p<0.0001$) were significant. By the LSD method ($\alpha=0.05$) the grid menu approach was found to be more efficient than the pull-down menu and the pull-down menu was better than the fisheye menu for state and website selection (LSD = 212.9).

The participants seldom made errors but they did make more errors selecting a website using the fisheye menu than with other menus (Figure 4.4). Especially when the number of selection options was large, error rate increased. Subjects complained about the sensitive movement of the fisheye menu during selection of the options although they

understood the focus lock mode. Some subjects reported that they needed more time and practice to use the fisheye menu effectively, a similar observation also made by Bederson (2000).

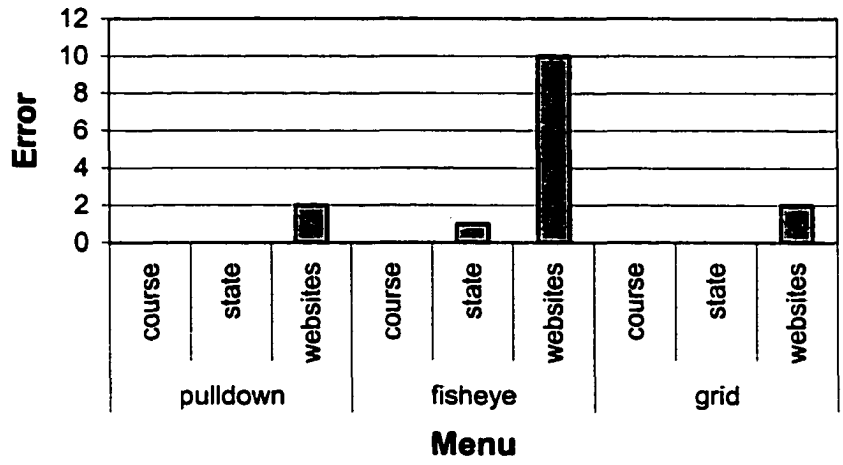


Figure 4.4. Selection error

Menu-items were grouped by their alphanumeric locations to allow comparison of performance time differences based on the location of a menu-item within the whole menu. The option positions were divided into 3 sections. The first 1/3 of menu-items were defined as top, the second 1/3 of menu-items were grouped as middle, and the rest were classified as bottom. For example, menu-items from Louisiana State to Ohio State were termed the middle group based on their location within the state lists. Performance times according to the location are presented in Table 4.2 and summarized in Figure 4.5. The analysis of variance is also shown in Table 4.3.

For the state and website selection within the top location, the pull-down and the grid menus performed better than the fisheye menu (Figure 4.5a). Within the middle location for

course selection, the pull-down and the fisheye menu required less time than the grid menu, but for the state and website selection, the grid menu was significantly better than the other menu styles (Figure 4.5b). For items in the bottom location, no significant difference in performance time was observed among the menus for course selection. However, for the state and website selection, the grid menu was more efficient than the other menus (Figure 4.5c).

Table 4.2. Performance time (ms) according to the location of the menu-items (mean, SD)

Menu-Item	Location within menu	Pull-down	Fisheye	Grid
28IE courses	Top	1556.63 (654.94)	1622.56 (798.89)	1672.03 (579.67)
	Middle	1896.39 (561.67)	1852.42 (479.89)	2335.86 (961.38)
	Bottom	1946.56 (503.38)	2125.00 (1100.27)	2158.14 (915.72)
50 States	Top	1672.09 (516.82)	2613.62 (1190.94)	1800.50 (483.01)
	Middle	2791.3 (1174.57)	3387.25 (1214.62)	2180.3 (844.30)
	Bottom	3463.37 (1227.63)	3249.67 (1473.36)	2283.57 (735.52)
100 Web-sites	Top	2192.80 (861.73)	4324.43 (2625.02)	2243.60 (757.38)
	Middle	4756.88 (1208.82)	6542.66 (3266.16)	2774.84 (924.26)
	Bottom	4862.05 (2111.28)	4803.81 (2589.87)	2576.26 (804.96)

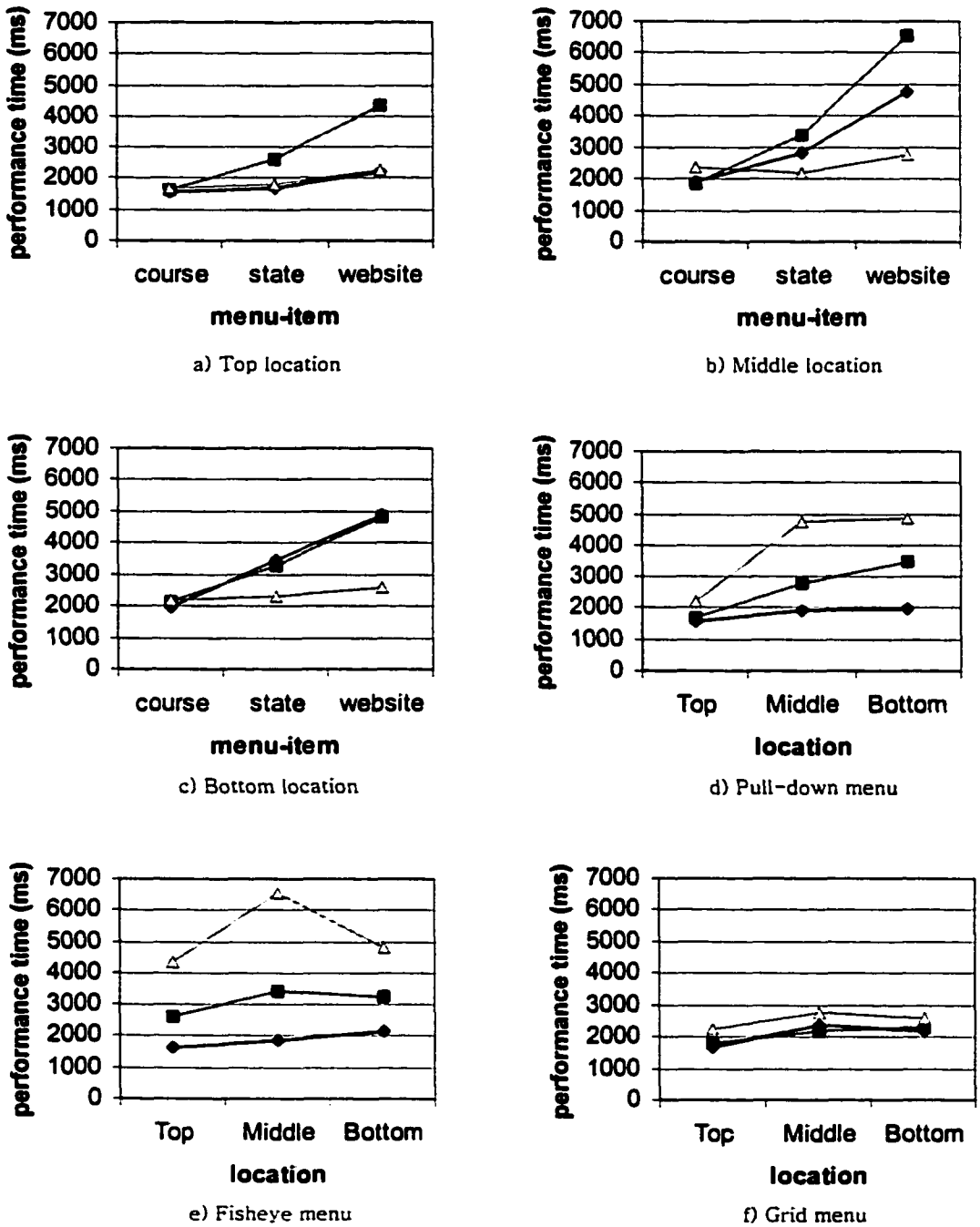


Figure 4.5. Performance time according to location and menu
a) ~ c) diamond: pull-down, square: fisheye, and triangle: grid
d) ~ f) diamond: course, square: state, and triangle: website

Table 4.3. ANOVA table for the performance time

Source of Variation	DF	MS	F_0
Menu Type	2	102389924	57.27
Length (Option)	2	314594649	175.96
Location (Option)	2	84989524	47.54
Menu Type * Length	4	55011785	30.77
Menu Type * Location	4	12886620	7.21
Length * Location	4	13375803	7.48
Menu Type*Length*Location	8	7175914	4.01
Error	909	1787851	

We found that as the length of menu becomes longer (website selection) performance time increased when subjects selected middle-placed items (Figure 4.5d ~ 4.5f). The performance time of the fisheye menu was greatest when choosing menu-items located in the middle for state and website selection. The performance time required to select a bottom menu-item was less than the middle options with the fisheye menu (Figure 4.5e). The grid menu was more efficient than the other menus for state and website selection. In addition, the performance time for the grid menu was less affected by the length of the menu and the location of the wanted options (Figure 4.5f).

Usability Measurement

After completing the experiment, the subjects were given a questionnaire on which 12 statements (4 usability factors × 3 menu types) of usability were presented with 5-point Likert scale. A strongly agree response was scored "5" with a strongly disagree a "1". The results of the usability test are given in Figure 4.6.

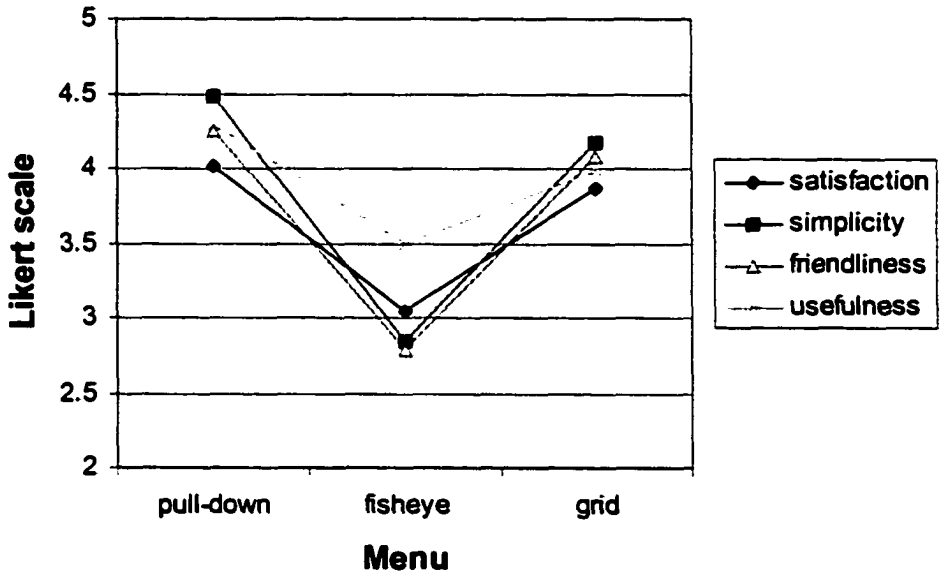


Figure 4.6. Usability test results

In this evaluation, the pull-down and grid menu were significantly better on the satisfaction ($F_{2, 153}$=19.56, p<0.0001), simplicity ($F_{2, 153}$=60.52, p<0.0001), user friendliness ($F_{2, 153}$=45.25, p<0.0001), and usefulness ($F_{2, 153}$=10.59, p<0.0001) characteristics than the other menu styles. There was no significant difference between the pull-down and grid menu. Twenty-two subjects felt the grid menu was the best menu approach as they felt it was easiest,

displaying all menu-items at once, and did not require any additional scrolling or dragging to see all possible options. Seventeen subjects preferred the pull-down menu because it was familiar, easiest, and occupied the least space. Thirteen subjects preferred the fisheye menu as they felt the style was fast and neat.

DISCUSSION

Performance time was less affected by the increase of menu length and locations of menu-items when a grid menu was employed. Grid menus were more robust and efficient with respect to the position of the menu-item and length of the item list. As menus became longer the grid menu gave better performance results as compared to the pull-down and the fisheye types.

To effectively use the fisheye menu, users need more practice than with other menu types. Without this additional practice, users prefer the grid or pull-down menus to the fisheye whose error rate is higher than the other menu types. Even though users knew of the focus lock mode technology, they sometimes forget to use the function and needed time to get familiar with the method. Users also needed more search and selection time with the fisheye menu when the menu-item was located in the middle of the long menu list and menu size was medium.

The pull-down menu was believed satisfactory, simple, user friendly and useful. In a certain situation (top location), as it allowed as good a performance as the grid menu. However, considering its efficiency and usability, the grid menu can be a good alternative menu if the list length is medium.

REFERENCES

Bederson, B. B. (2000). Fisheye menus. *User Interface and Software Technology (UIST '00)*, 217-225.

Byrne, M. D., Anderson, J. R., Douglass, S., & Matessa, M. (1999). Eye tracking the visual search of click-down menus. *Proceedings of CHI '99 Conference on Human Factors in Computing Systems*, 402-409, ACM, New York.

Furnas, G. W. (1986). Generalized fisheye views. *Proceedings of CHI '86 Conference on Human Factors in Computing Systems*, 16-23, ACM, New York.

Kurtenbach, G., Fitzmaurice, G. W., Owen, R. N., & Baudel, T. (1999). The hotbox: efficient access to a large number of menu-items. *Proceedings of CHI '99 Conference on Human Factors in Computing Systems*, 231-237, ACM, New York.

Perlman, G. (1984). Making the right choices with menus. In Shackel, B. (Ed.), *Human-Computer Interaction INTERACT '84*, 317-321.

Walker, N., Smelcer, J. B., & Nilsen, E. (1991). Optimizing Speed and Accuracy of Menu Selection: A Comparison of Walking and Pull-Down Menus. *International journal of Man-Machine Studies*, 35(6), 871-890.

CHAPTER 5. AN INTERACTION MODEL FOR LONGER PULL-DOWN MENUS

A paper to be submitted International Journal of Human-Computer Studies

Hong-In Cheng and Patrick E. Patterson

Abstract

Previous studies investigated a variety of interaction models for menu use, primarily evaluating relatively short menus. In this study, long pull-down menus were studied through a menu-item selection experiment. Experimental data showed proportional selection time increased based on menu position and declined for menu-items lower in a menu's format when there were 28 alternatives while additional time was needed for 50 options because of scrolling. Fitts' law was applied to scrolling for longer menus. Our model assumes 1) the first eye fixation is located at the top, middle, or end of a menu, 2) menu scanning is either downward or upward, 3) the mouse is moved top-down slowly while target is scanned, 4) the user moves mouse quickly to the targets located on the edges of a menu, and 5) three items are scanned at a time. The proposed model in this study showed better fit than other models and possible improvements with menu were suggested.

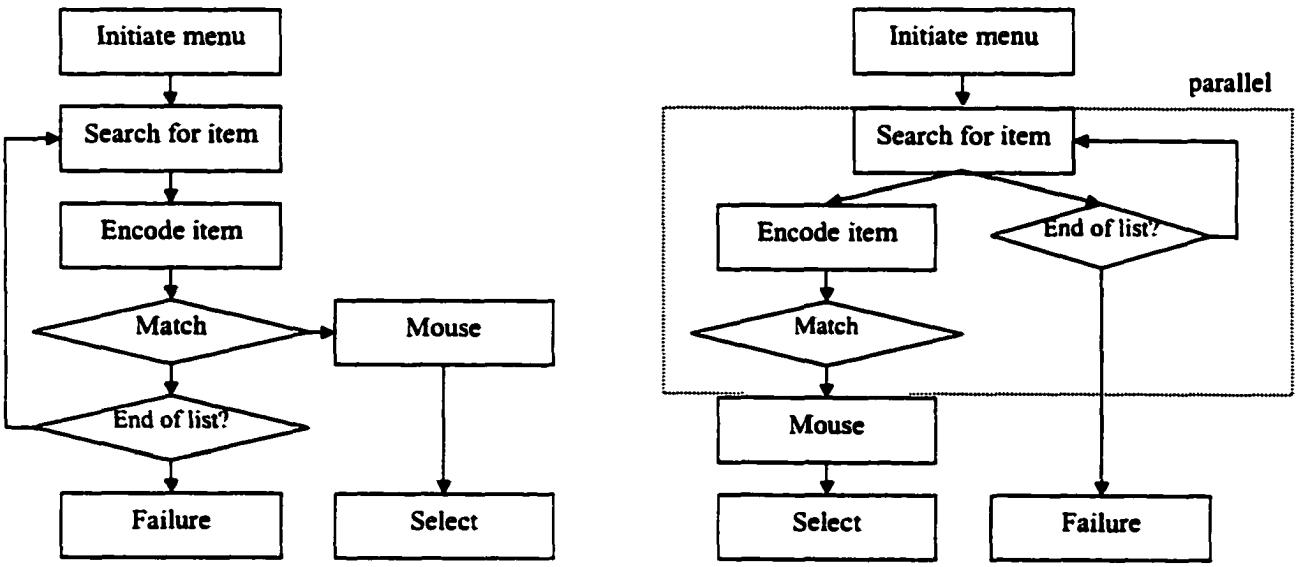
INTRODUCTION

The pull-down menu is a popular interaction method in modern user interfaces. Menu selection includes not only perceptive and cognitive elements, but also motor behavior. To

activate a pull-down menu a user clicks on the menu title, searches for a target menu-item, makes a judgment and decision, and selects the needed option.

When searching alternatives, users exhibit two distinct eye movements. The eyes stay stationary for a short time at points for visual input, termed fixation. A movement between two fixation points is referred to as a saccade, whose trajectory is called a scan path.

There are two well-known models describing menu selection (Figure 5.1). The serial model assumes that users perceive an item, recognize the target, and clicks on an item in serial order. The parallel model presumes that a human's gaze moves and checks the items in working memory simultaneously, and then chooses the target when it is detected.



a) Serial processing model

b) Parallel processing model

Figure 5.1. Menu selection models

Norman (1991) reported that menu selection is a serial process of search, choice, and response. It was proposed that visual matching needs to search then select an explicitly known target with the extent of similarity and vagueness of alternatives influencing the search time. For a partially specified target, encoding and evaluation processes are utilized because the user needs to read, understand, and assess each item. He presented three search models (Figure 5.2).

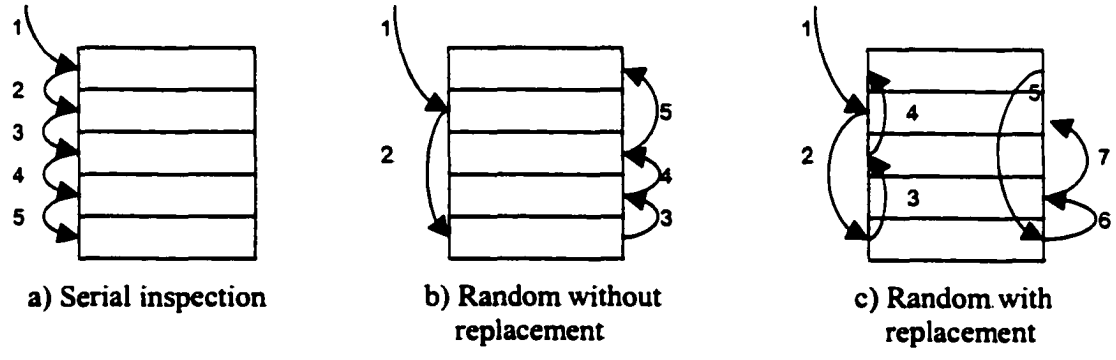


Figure 5.2. Three models of visual search (Norman 1991)

The user examines each item in a top-down manner without skipping an item if using a serial inspection method. Menu-items are viewed without using a pattern or repeated scan in the random inspection without replacement method. In the random search with replacement method, items can be scanned repeatedly.

Search strategies are also classified by the stopping rule used. In a self-terminating search, the user stops searching when the target is encountered. An exhaustive search requires examining each item until the target is detected. Menu-items are viewed again if the

target is not found after all items have been observed. A self-terminating search is typically applied when the user knows target exactly.

The menu selection process has been compared with the process used in choice reaction. Choice reaction usually needs to select appropriate response similar to menu selection, which requires menu-item scanning. Donders proposed that choice reaction time could be obtained by adding up simple reaction, stimulus classification, and response selection time (Kantowitz et al. 1983).

Hick (1952) and Hyman (1953) suggested that choice reaction time is a function of the number of alternatives and formulated a quantitative model, below.

$$CT = a + b \log_2 N \quad \cdots\cdots (1)$$

where CT is choice time, a is simple reaction time, b is constant determined by experiment, and N is the number of alternatives.

Motor response time was related to the target distance and the difficulty of selecting the target (Norman 1991). For an analog-pointing device, Fitts' law predicts the movement time:

$$MT = a + b \log_2 (A/W) \quad \cdots\cdots (2)$$

where MT is movement time, a and b are constants, A is distance to target, W is the width of target, and logarithmic element is the index of difficulty. Two variations of the law were suggested by Welford (1968) and Mackenzie (1989):

$$MT = a + b\log_2(A/W + 0.5) \quad \cdots\cdots (2')$$

$$MT = a + b\log_2(A/W + 1) \quad \cdots\cdots (2'')$$

Equation 2'' is the Shannon formulation and is preferred as it fits slightly better to data, and the index of difficulty is always positive (MacKenzie 1992).

Menu selection using a pull-down menu is two-dimensional. Mackenzie and Buxton (1992) applied Fitts' law to two-dimensional target selection. Fitts' law was originally designed for one-dimensional movement task and it does not fit well to a two dimensional task (Figure 5.3). Experimental data showed that using the smaller of target's width (W) or height (H) for the target width gives the best results.

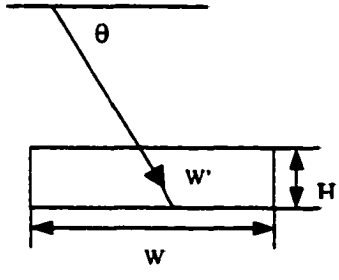


Figure 5.3. Possible width of pull-down menu (MacKenzie and Buxton 1992)

A different linear function can be applied to discrete pointing objects like arrow keys (Norman 1991),

$$R = a(d_x + d_y) + b \quad \cdots\cdots (3)$$

where d_x and d_y are x and y displacements of the cursor position from the target and a and b are constants.

Lee and MacGregor (1985) reported that selection time depends on searching strategy, reading speed, and key press time. The selection time was formulated:

$$S = (E(A) \times t) + k + c \quad \cdots\cdots (4)$$

where S is selection time, E(A) is the expected number of alternatives, t is the time to read a single option, k is key press time, and c is computer response time. It was calculated that using from 4 to 8 alternatives per page minimizes search time for a computerized information retrieval system.

The Epic model (Hornof and Kieras 1997) indicated that 1) users employ both sequential and random searching strategy for scanning menu-items, 2) multiple items are searched in parallel, 3) the travel distance of eye saccades are constant, and 4) mouse movement occurs after a target is sensed. The ACT-R (Anderson et al. 1997) model predicted that 1) top-down search is used, 2) only single items are examined, 3) the travel distance of saccades vary, and 4) mouse movements follow the saccades before the discovery of the chosen menu-item.

Nielsen (1991) performed an experiment with menus having three, six, and nine options. Subjects selected single digit menu-items randomly arranged for each trial. The results showed that a linear relationship exist between the position of menu-items and selection time. The data also indicated that Fitts' law does not explain menu selection time

although Nielsen's menu was not of typical construction since menu items were single digit and randomly arranged for each selection.

Aalton et al. (1998) reported that menu-items are scanned in sequential sweeps by analyzing the scan path. However, users in this study could not anticipate the location of the menu-items because grouped menu-items were used and the menu-items were sorted in a random order within the groups.

Byrne et al. (1999) used Nielsen's menu with six, nine, and twelve items and proposed that 1) the primary search strategy is top-down, 2) some items are skipped during the top-down search, 3) these skipped items are occasionally found by backtracking, and 4) the initial fixation is located on one of the first three menu-items. It was suggested that a more suitable model might lie between the EPIC and the ACT-R model. Top-down search with occasional backtracking was believed a plausible model for short menus and the use of top-to-bottom search was proposed primarily for longer menus.

Hinckley et al. (2002) distinguished two distinct behaviors of mouse movement. Users move a mouse relatively slowly when the distance is small but if the distance is longer the user moves the mouse more rapidly. The experimental results also suggested that Fitts' law applied to the scrolling times.

Previous studies used relatively short menus containing several menu-items that were not of a practical design. For example, alternatives were digits and the order of the menu-items was random (Hornof and Kieras 1997, 1999, Byrne et al. 1999). More recently, long menus are often used for e-commerce or other applications (Cheng and Patterson 2002). These longer menus require users to scroll up and down to search and select the target. It is not known how users interact with pull-down menus that require scrolling. This study

examined eye-movement, search strategy, and mouse movement using relatively long menus to find an appropriate model for the interaction. Alphanumerically ordered menus were employed in the study.

METHOD

Subjects

Fifty-two subjects (33 male, 19 female) from an introductory ergonomic class at Iowa State University participated in the study and received extra class credit. The subject ages ranged from 19 to 39 (mean=21.2, SD=3.16). Ninety six percent of subjects indicated they were familiar with the use of pull-down menus through their familiarity with a variety of software.

Interface

Two different applications were designed for each menu. The first task was to select one of 28 IE department undergraduate courses at Iowa State University and in the second, one of 50 states. Users did not need to use any scrolling with the course menu; however, scrolling or clicking down through the menu-items was necessary to select a state because not all of the menu-items fit into a single screen (Figure 5.4)

Procedure

Purpose, procedure, risks, and benefits of the experiments were explained to subjects and informed consent was obtained. The participants then selected an experimental sheet from a stack of randomly ordered papers and filled out personal information before the

experiment. The experimental sheet was composed of three sections: 1) name, age, and gender, 2) three randomly pre-selected items for each menu, and 3) record of the response time.

a) 28 courses b) 50 states

Figure 5.4. Pull-down menu screen shot

Each subject was presented with the two menus and given a short time to examine the each menu and the order of the items for both menus. Four randomly selected trial items were also chosen by the participants for each menu and the mechanism of performance time measurement was explained. When they felt comfortable with the menu and the environment, actual options were given to the subjects to be selected on the experimental sheet. The participants selected the explicit menu item twice while the order of menu presentation was random. Menus were programmed to always appear at the same position on the screen.

RESULTS

The mean times of menu-item selection with the IE courses (Figure 5.5) showed a gradual increase of search time dependent on the position of the item, decreasing at the end of the menu. We developed a basic model and changed each assumption to provide a better fitting model to experimental data. Our model assumes that 1) first eye position is located at the top, middle, or end of menu, 2) menu scanning is either downward or upward, 3) the mouse is moved top-down slowly while target is scanned, 4) the user moves mouse quickly to the targets located at edge, and 5) three items are scanned at a time. Based on these assumptions an equation was obtained using linear regression (Figure 5.5).

$$ST = 217 + 13.489\log_2(N) + 479.455\log_2(\frac{0.9 \times A}{W} + 1), \quad r^2 = 0.83 \cdots\cdots (5)$$

where N is the number of alternatives to scan, A is distance to target, W is the smaller dimension of height and width, and 90 percent of actual travel distance is considered because

the mouse presumably moved 10 percent of the distance while reading the menu-items. The last 5 items were assumed to be closer because of the rapid mouse movement towards the edge target. The edge target represents the location of the item that is near the border of a menu. Edge targets induce rapid mouse movement because user can skip to the lower boundary without encoding menu-items.

A model ignoring quick edge movement used in the above model did not represent the users' behavior well (r^2 = 0.705, Figure 5.6). When the searching and movement were assumed to occur serially, the result was also not satisfactory (r^2=0.706, Figure 5.6).

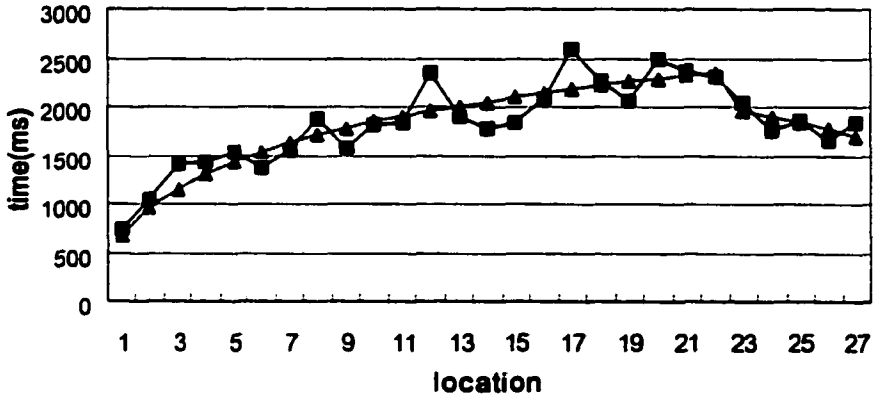


Figure 5.5. The selection time of IE courses
(Square: experimental data, Triangle: expected time)

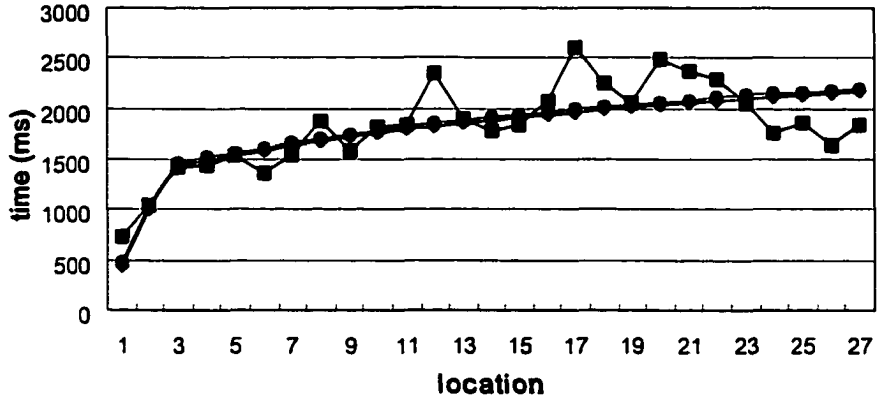


Figure 5.6. The selection time of IE courses
(Square: experimental data, Circle: no edge movement, Diamond: serial search)

The pull-down menu with 50 states required scrolling to select an item located lower in the menu structure because every item could not be displayed simultaneously on a screen. About thirty alternatives were in view without scrolling (Figure 5.4). Data shows a steady time increase up to the thirtieth item, swift growth from thirty-first to forty-third item, and a decrease for items at the end of the menu (Figure 5.7).

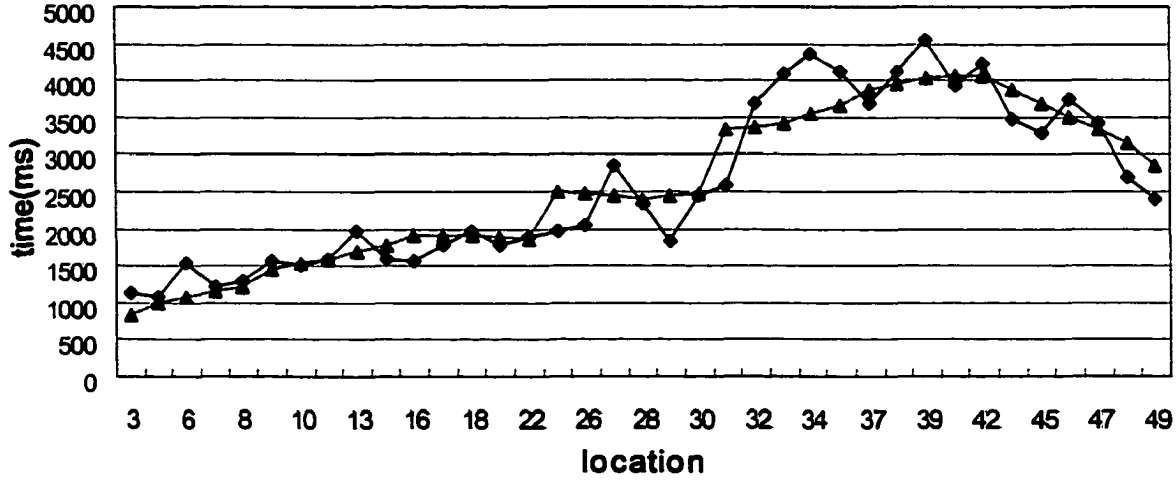


Figure 5.7. The selection time of 50 states
(Diamond: experimental data, Triangle: expected time)

The model for selecting the IE 28 courses selection was adapted to that of the 50 states menu by assuming that 1) the initial fixation stays at the top or the bottom of the screen, 2) menu search is either downward or upward, 3) mouse moves down slowly while target is scanned, 4) user moves mouse rapidly to the bottom without pause for the edge target, 5) three items are scanned at a time, and 6) scrolling time is explained by Fitts' law (Hinckley et al. 2002). The model was formulated, using linear regression, as ($r^2 = 0.891$)

$$ST = 642.692 + 221.511\log_2(N) + 216.84\log_2(\frac{0.9 \times A}{W} + 1) + 656.007\log_2(\frac{S}{W})$$

where N is the number of menu-items to scan, A is the distance to target, W is the smaller dimension of height and width, and S is scrolling distance. When the assumption about quick edge movement is ignored, the data was not explained well ($r^2 = 0.671$, Figure 5.8) and serial mouse movement also did not fit well ($r^2 = 0.672$, Figure 5.8). The probability of scrolling usage is assumed since the upper 30 items can be selected without scrolling, however users sometimes scroll to search or select them. Probability of scrolling usage is assumed and given in the table 5.1.

Another model was then developed by presuming 1) initial fixation is located at the first menu-item, 2) search strategy is top-down, 3) mouse moves 1 percent of actual selection distance during scanning, 4) mouse moves rapidly to the edge target, and 5) three items are scanned at a time. The mathematical model using these assumptions was ($r^2 = 0.884$),

$$ST = 1955.806 - 281.001\log_2(N) - 177.235\log_2(\frac{0.9 \times A}{W} + 1) + 773.056\log_2(\frac{S}{W})$$

When the edge benefit and preceding mouse movement were disregarded, experimental data were not explained adequately.

Table 5.1. Probability of scrolling (0 is top of menu, 50 is bottom)

Location of item	Probability
0 ~ 10	0.1
11 ~ 15	0.2
16 ~ 20	0.4
21 ~ 30	0.6
31 ~ 50	1

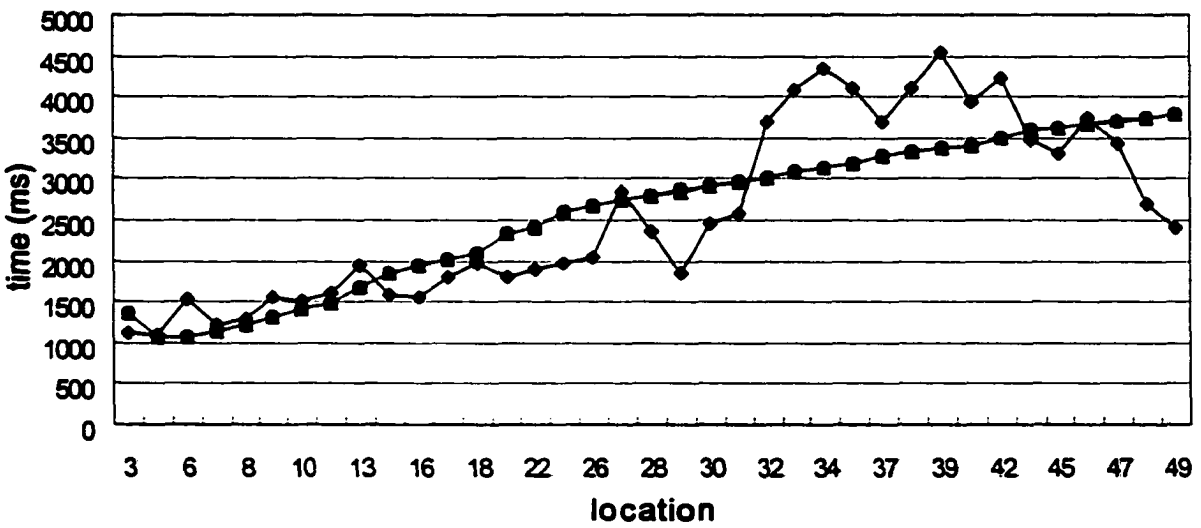


Figure 5.8. The selection time of 50 states
(Diamond: experimental data, Circle: no edge movement, Triangle: serial search)

DISCUSSION

Plausible models have been developed for the interaction with the menu by typically examining short pull-down menus. In this study, relatively long pull-down menus were designed and studied to examine the interaction with the menu. The first menu, containing 28 university courses, did not require scrolling but 50 states menu did need scrolling to access the lower menu-items.

Selection time of the course menu showed two main characteristics (Figure 5.5): a proportional time increase related to menu position and a selection time decrease at the lower menu. The first eye location is believed to go to the top, middle, or end of menu because users can guess the rough location of menu-items in advance if alternatives are alphanumerically arranged. Downward or upward scanning is then employed from the fixation. For example, downward search would be used when the target is located below the fixation.

Unconscious cursor movements following saccade occurred as conjectured. Although we don't know whether the movement is intentional or not, subjects reduced selection time by using this preliminary motion. When a user recognizes the target was close to the end of a menu, the mouse pointer flicks to the final approximate location and the target is chosen quickly. Scrolling was predicted precisely by Fitts' law. It was shown that the longer menu selection process is similar to the short menu choice process except for the addition of scrolling and the position of the first fixation.

An abrupt increase of the selection time at thirty-first menu-item within the 50 states menu was the result of scrolling for lower menu-item selection. The first fixation was not located in the middle of the menu shown on a screen because it is difficult to guess where a

specific item may be located within such a long list. The first fixation is assumed to be located the top or bottom of the menu displayed. Considering the whole menu, the first fixation actually goes to the top, middle, or bottom items like the course menu.

Users often moved cursor down to the lower items even if a target item was located such that scrolling was not necessary. To explain this phenomenon, stochastic scrolling was introduced to the model. Scrolling time was forecasted well with Fitts' law as Hinckely et al. (2002) reported. As the menu became longer, our model was a better fit while the other assumptions did not show similar results.

A top-down serial scan model also gave good results. Nielsen's menu showed that initial fixation was located at the first item with high frequency (Byrne et al. 1999). However users could not predict the location with the menu because menu-items were rearranged randomly in each trial. With the menu reasonably arranged, our model is more persuasive.

Three possible improvements with menu can be directly induced from the study: more efficient first fixation, better scrolling, and using quick edge movement. Menu designers need to consider how users can cast their first fixation at a more advantageous position. Indexed menus can be good examples to enhance the first eye position. New scrolling methods such as automatic scrolling can be studied also. Edge target idea can be used wildly, especially for emergency button.

REFERENCES

Aaltonen, A., Hyrskykari, A. & Räihä, K. J. (1998). 101 spots, or how do users read menus?, *Proceedings of CHI '98 Conference on Human Factors in Computing Systems*, 132-139. ACM, New York.

Anderson, J. R., Matessa, M., & Lebiere, C. (1997). ACT-R: A theory of higher level cognition and its relation to visual attention. *Human-Computer Interaction*, 12, 439-462.

Byrne, M. D., Anderson, J. R., Douglass, S., & Mtessa, M. (1999). Eye tracking the visual search of click-down menu, *Proceedings of CHI '99 Conference on Human Factors in Computing Systems*, 402-409. ACM, New York.

Cheng, H. & Patterson, P. E. (2002). The grid menu: efficient and robust selection of menu-items, *Proceedings of the Human Factors and Ergonomics Society 46th Annual meeting*, 1281-1285, Human factors and Ergonomics Society.

Farris, J. S., Jones, K. S., & Anders, B. A. (2001). Acquisition speed with targets on the edge of the screen: and application of Fitts' law to commonly used web browser controls, *Proceedings of the Human Factors and Ergonomics Society 45th Annual meeting*, 1205-1209, Human Factors and Ergonomics Society.

Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement, *Journal of Experimental Psychology*, 47, 381-391.

Hick, W. E. (1952). On the rate of gain of information, *Journal of Experimental Psychology*, 4, 11-26.

Hinckley, K., Cutrell, E., Bathiche, S., & Muss, T. (2002). Quantitative analysis of scrolling techniques, *Proceedings of CHI 2002 Conference on Human Factors in Computing Systems*, 65-72. ACM, New York.

Hornof, A. J., & Kieras, D. E. (1997). Cognitive modeling reveals menu search is both random and systematic. *Proceedings of CHI '97 Conference on Human Factors in Computing Systems*, 107-114. ACM, New York.

Hornof, A. J. & Kieras, D. E. (1999). Cognitive modeling demonstrates how people use anticipated location knowledge of menu items. *Proceedings of CHI '99 Conference on Human Factors in Computing Systems*, 410-417. ACM, New York.

Hyman, R. (1953). Stimulus information as a determinant of reaction time. *Journal of Experimental Psychology*, 45, 188-199.

Kantowitz, B. H., & Sorkin, R. D. (1983). *Human factors*. New York: Wiley.

Lee, E. & MacGregor, J. (1985). Minimizing user search time in menu retrieval systems. *Human Factors*, 27 (2), 157-162.

MacKenzie, I. S. & Buxton, W. (1992). Extending Fitts' law to two-dimensional tasks, *Proceedings of CHI '92 Conference on Human Factors in Computing Systems*, 219-225. ACM, New York.

Nielsen, E. L. (1991). *Perceptual-motor control in human computer interaction* (Tech. Rep. No. 37), Ann, Arbor Michigan: The Cognitive Science and Machine Intelligence Laboratory, The University of Michigan.

CHAPTER 6. ICONIC HYPERLINK ON E-COMMERCE WEBSITES

A paper to be submitted Applied Ergonomics

Hong-In Cheng and Patrick E. Patterson

Abstract

Proper use of iconic interfaces reduces system complexity and helps users interact with systems easily. Some icons used on web sites are ambiguous because of the short history of web sites, the lack of studies, and careless use of icons. In this study, visual icons being used on e-business web sites were examined by population stereotypy and categorized into three groups: identifiable, medium, and vague. Some icons did not appear to make any sense. Representative icons from each group were tested by comparing the selection performance. Better performance was observed with identifiable and medium icons. Web designers must consider whether icons are identifiable in designing web sites because not identifiable icons may convey different meanings along with their intended meaning.

INTRODUCTION

Pictographic interfaces are believed to reduce system complexity and decrease mental load (Howel and Fuchs 1968, Lodding 1983, Rohr 1984, and Rohr and Keppel 1984). In many cases, icons represent commands and system state (Rogers 1986). Iconic interfaces concern the images to convey meaning nonverbally and are characterized by type, form, and

color. The pictures are chosen by resemblance (pictograph), analogy (symbol), or socially learned custom (sign). Standing et al. (1970) reported that pictures are remembered easily over long times and usually give better recall than text. Aversano et al. (2002) presented iconic interfaces to help novice users understand a complicated relational database model. Through a search task, pictorial navigation aids were shown useful in making labels unambiguous (Egido and Patterson 1988). Usually the most effective icon type is a concrete object which maps directly to the referent with the analogical icon being less effective (Rogers 1984). Articulatory distance, representing difference in meaning between a picture and what it represents was shown to influence reaction time in design (Blankenberger and Hahn 1991).

Howel and Fuchs (1968) proposed a population stereotype measure and reported that this can be utilized to advantage in symbol development.

$$W = \frac{Fx}{Fy} \times 100 \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (1)$$

where W is population stereotype measure, Fx and Fy are frequencies of correct response and all response respectively. They described how to generate military signs using the technique. Most modern software uses icon to provide users with a pictorial interface which acts as a physical metaphor to make software more user friendly and easier to use with less training. However, not all icons convey the intended meaning to users (Rogers 1986).

E-commerce websites also use the iconic interface to allow customers to move to appropriate web page, submit an order, and retrieve information. For example, the shopping

cart icon, often found on the e-commerce websites, is used to check out products after selecting goods. Web designers face the decision whether to use an iconic, or a command-based interface, or a combination of both when designing web sites allowing quick, accurate, easy interaction.

Pictographic symbols in public places such as airports, roadways, and public buildings have been well studied (Caron et al. 1980). However pictographic symbols as iconic interfaces on the web has not been studied in detail. In semiotics, it's believed that all symbols should be consistent to meet their unique communication needs. Few symbolic icons are consistently used on e-commerce sites because of the short history of web sites and the lack of studies.

Web designers currently do not have any books of iconic interfaces from which to choose the best picture for a given situation. In this study, 1) visual icons being used on e-business web sites were categorized and investigated based on population stereotypy, 2) representative icons from each group were evaluated by testing selection performance, and 3) a methodology to select and use an appropriate website interface are suggested.

EXPERIMENT 1

The primary objective of the first experiment was to determine the quality of icons by examining identifiability. Twenty-five icons were collected from e-business web sites mainly introduced by Napier et al. (2001). Subjects were shown the icons and asked to determine the function of each icon. Subjects were informed that the icons had been collected from e-business web sites.

Method

Thirty-eight subjects (25 male, 13 female) from an introductory ergonomic class at Iowa State University participated in the study and received extra class credit. Their ages ranged from 19 to 27 (mean=21.13, SD=1.58). Eight nine percent of subjects indicated they have had experience purchasing goods on e-commerce websites.

Each subject was given a brief explanation of the experiment and informed consent was obtained. A questionnaire was given to each subject to evaluate exactly how users identify the function of each icon. Subjects recalled or guessed the intended function of each icon and wrote their thoughts in free form.

Results

According to the stereotypy suggested by Howel and Fuchs (1968), icons were grouped into 3 categories: identifiable (60% ~ 100%), medium (30% ~ 59%), and vague (0% ~ 29%) icons. Some examples are given in table 6.1. Responses were considered correct if a key word or similar description was embedded in the answer.

A security symbol with lock (76.3%) and shopping bag (60.5%) were also grouped as identifiable icons. Palm tree (57.9%) for purchase of vacation package and letter "H" and door (42.1%) representing hotel reservation were medium icons. Telephone (7.8%) for customer support, heart (5.3%) and shooting star (0%) for wish list, pencil (0%) for checking account, plug (0%) for login and document (0%) for reviewing order history were not well understood by subjects. Some icons did not appear to make any sense although they were selected from actual e-business web sites.

Table 6.1. Classification of icons

	Icon	Function	Stereotype (%)
Identifiable		Transfer to help web page	92.1
		Initiate e-mail web page	86.6
		Check out products	81.6
Medium		Load information web page	55.26
		Purchase airline ticket	55.3
		Check out products	34.2
Vague		Check out products Check account	2.63 0
		Check order status	15.8
		Register	5.3
		Check account	0
		Show a list of favorite products	0

Interestingly some icons were used for different meanings. Check mark was employed to represent to checkout products and to check user's account (Table 6.1). Various icons were used for the same hyperlink over web sites. Shopping bag and cart were used for some purpose for example. Several different icons from the same object were also observed.

EXPERIMENT 2

To explore actual effects on performance time due to icon usage and provide suggestion for designers, another empirical study was designed based on the results from the previous experiment.

Method

Nine (3 categories × 3 formats) e-commerce web pages were built using identifiable (), medium (), and vague icons (). Icon, text, and icon + text formats were used to investigate hyperlinks on e-commerce web sites. General commercial web site styles were employed to design simulated web sites (Figure 6.1). Company name and logo was located top, hyperlink menus were displayed just under the title, and other information was placed in the rest of screen using a grid structure.

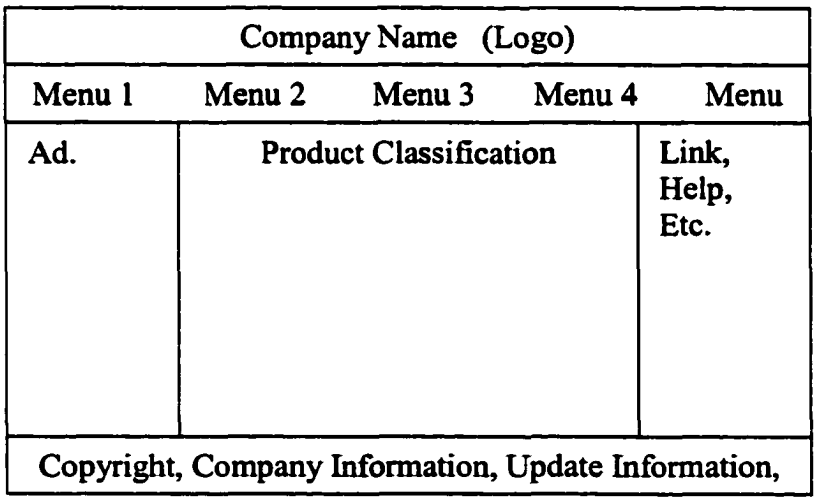


Figure 6.1. Basic format of simulating web page

A between–subject design was used in the experiment because of the learning effect. Twenty-one Iowa State University students (14 male and 7 female) participated in the experiment and each subject selected one of three format groups. Appropriate situations and tasks were given to subjects before selecting each hyperlink. For example, 1) product was already ordered, 2) subject wants to know where the product is now. It could still be in a warehouse, being delivered, or already delivered and stored in delivery company, and 3) then selects a hyperlink to retrieve the delivery information.

The experiment was a randomized factorial design. There were two factors (category and format) and each factor had three levels (category: identifiable, medium, and vague icon, format: icon, text, and icon + text). Independent variables were category and format with target selection time as the dependent variable.

Results

The performance times due to the independent variables are given in table 6.2 and the ANOVA table is shown in table 6.3. The experimental errors are assumed independently distributed in the normal distribution for the analysis of variance. Significant main effects were detected for category ($F_{2,\ 58} = 13.4816$, $p<.0001$) and format ($F_{2,\ 58} = 8.1295$, $p<.001$). There was also a significant interaction ($F_{2,\ 58} = 6.825$, $p<.01$). The LSD (Least Square Difference) method ($\alpha=.05$) showed identifiable and medium icons are significantly more efficient than vague icons. No significant difference was detected between identifiable and medium icons. Icon + text and text only format were significantly better than icon format. Text was as efficient as the combined format. However, table 6.2 and figure 6.2 show and identifiable icon is competitive with the other formats.

Table 6.2. Performance time (ms) due to the category and format (mean, STD)

		Category		
		Identifiable	Medium	Vague
Format	Icon	1680.29 (164.47)	2910.29 (453.34)	5990.43 (2633.46)
	Text	1651 (374.59)	1699.72 (373.51)	2844 (1167.23)
	Icon + Text	2072.71 (407.76)	2230.86 (1074.49)	2463.86 (599.8)

Table 6.3. ANOVA table for the performance time

Source of Variation	DF	Sum of Squares	Mean Square	F ratio
Category	2	44,051,888	22,025,944	18.8975
Type	2	26,563,456	13,281,728	11.3953
Interaction	4	31,819,561	7,954,890	6.8250
Error	54	62,939,603	1,165,548	
Total	62	165,374,508		

Figure 6.2 illustrates the experimental data. When an icon is identifiable, icon and text can be effectively employed. Otherwise, text shows the best performance for all situations. Icon + text hyperlink required a little more time than did the text interface because users need to encode text and icon when combinational links used. For all formats, identifiable icons showed better results.

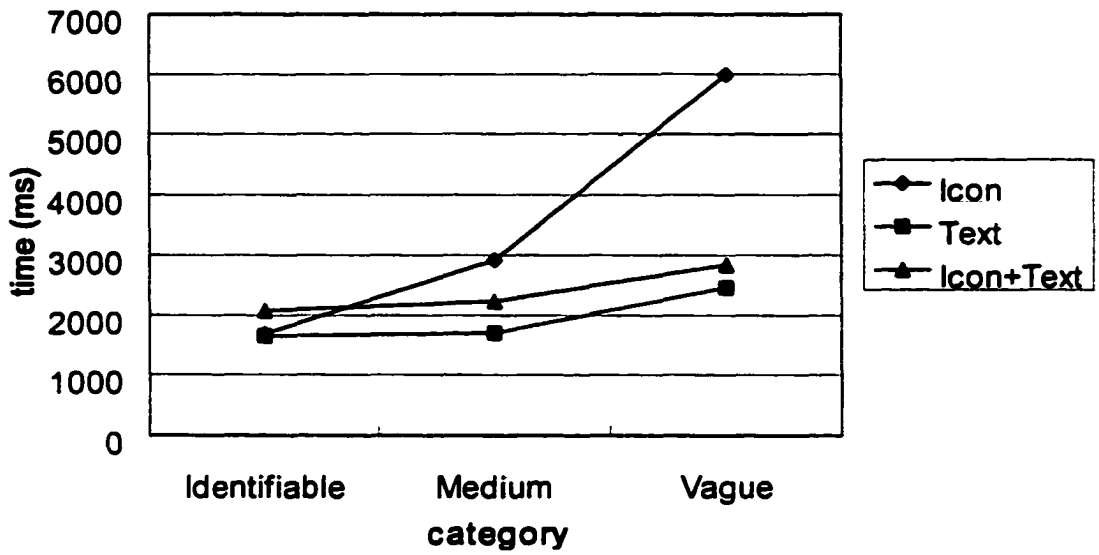


Figure 6.2. Performance time

DISCUSSION

Iconic interface use on web sites is very important and more icons will be used on the web in the future. Many icons currently used on e-commerce web sites were not meaningful. Some icons also conveyed only different meanings along with their intended meaning. When web designers use icons on web sites, they must consider whether they are identifiable. We recommend the use of a pilot study rather than a self-test. If icons are not identifiable and brief text exists to represent the intended function, text would be a better hyperlink. Combinations of icon and text can be an alternative interface but needs more space and usually a little more time for identification. To encode text and icon requires more cognitive processing by a user.

Importantly, not all icons will guarantee a reduction in complexity and mental load. When icons are identifiable the results from previous studies hold, however, if the quality of

icons is not appropriate, icons can increase the vagueness. Icons should be cautiously designed, selected and used.

More research is needed to explore which icons are identifiable and how to design better icons. Only qualified icons must be used on the web sites to increase the usability of the web sites.

REFERENCES

Aversano, L., Canfora, G., Lucia, A. D., & Stefanucci, S. (2002). *Proceedings of 26th Annual International Computer Software Applications Conference*, 703-708.

Blankenberger, S. & Hahn, K. (1991). Effects of icon design on human-computer interaction, *International Journal of Man-Machine Studies*, 35 (3), 363-377.

Caron, J. P., Jamieson, D. G., & Dewar, R. E. (1980). Evaluating pictogram using semantic differential and classification technique, *Ergonomics*, 23 (2), 137-146.

Egido, C., & Patterson, J. (1988). Pictures and category labels as navigational aids for catalog browsing, *Proceedings of CHI '88 Conference on Human Factors in Computing Systems*, 127-132. ACM, New York.

Howell, W. C. & Fuchs, A. H. (1968). Population stereotypy in code design, *Organization Behavior and Human Performance*, 3, 310-339.

Lodding, K. N. (1983). Iconic interfacing, *IEEE Computer Graphics and Applications*, 3 (2), 11-12.

Napier, H. A., Judd, P. J., Rivers, O. N., & Wagner, S. W. (2001). *Creating a winning e-business*. United Kingdom: Course Technology.

Rohr, G. (1984). Understanding visual symbols, In IEEE Computer Society (Ed.).

Proceedings of IEEE 1984 workshop on visual Languages, 184-191, Silver Spring: IEEE Computers Society.

Rogers, Y. (1986). Evaluating the meaningfulness of icon sets to represent command operations, *Proceedings of CHI '86 Conference on Human Factors in Computing Systems*, 586-603. ACM, New York.

Rohr, G. & Keppel, E. (1984). Iconic interfaces: where to use and how to construct?. In H.W. Hendrick and O. Brown, Jr. (Ed.). *Human Factors in Organizational Design and Management*, 269-275.

Standing, L., Conezio, J., & Haber, R. N. (1970). Perception and memory for pictures: Single trail learning of 2560 visual stimuli. *Psychonomic Science*, 19, 73-74.

Hemenway, K. (1988). Psychological issues in the use of icons in command menus, P*roceedings of CHI '86 Conference on Human Factors in Computing Systems*, 21-24. ACM, New York

CHAPTER 7. GENERAL CONCLUSION

One of the most significant issues in Human Factors and Ergonomics is usability. Usability applies to customer product design, screen design, web design, process design, etc. This dissertation mainly focused on usability of human-computer interaction in e-commerce web sites.

Usability with data input tools on the web sites was studied in chapter 2. Proper use of existing standard input tools makes a user interface usable (Somborg 2000), but data input type does not determine which input tool must be used. We compared standard input tools using a hotel reservation simulation. For larger option lists pull-down menu was considered most satisfactory, simplest, and easiest to remember its usage but the text input box required the least amount of time to use. Radio box and list were best for binary data input, and time efficient for multiple choices situations. Pull-down menu was believed simpler and easier when the number of options was limited.

Existing web design guidelines do not contain much detail and often conflict each other. In chapter 3, more specific guidelines were proposed and important design elements for successful e-business were studied. Price, e-brand, and quick delivery were most important factors in the use of an e-bookstore and it might be same with most e-commerce companies. It was shown that web design might influence customers' purchase. A distinguishable and well-located search engine affects the usability of an online bookstore; an easy to use search engine influence user perceptions of a web site. Single column design made users feel that access to the web site was well organized. This study showed that

simplicity is more important to users than providing more information on e-business web sites.

Chapter 4 was devoted to menus with longer lists of options often used on the web sites. A grid menu was designed for the study and compared with pull-down and fisheye menus using performance time, error rate, user satisfaction, simplicity, user friendliness, usefulness and overall user preference of each menu. The grid menu was shown to be more efficient in selection time when there are from 50 to 100 menu-items and was less affected by the size of menu and location of menu-item within a menu.

Pull-down menus, the most often used menu type on web sites, was studied in detail in chapter 5 to find user behavior characteristics and suggest an interaction model. Based on the empirical data, a model was built by assuming that 1) the first eye fixation was located at the top, middle, or end of a menu, 2) menu scanning was either downward or upward, 3) the mouse was moved top-down slowly while target is scanned, 4) user moves mouse quickly to the targets located on the edge of menu, and 5) three items are scanned at a time. Three possible improvements with pull-down menu were also suggested.

Modern interfaces employ pictographic tools since to reduce complexity and mental load (Howel and Fuchs 1968, Lodding 1983, Rohr 1984, and Rohr and Keppel 1984). Iconic navigation aids are useful in disambiguating the labels (Egido and Patterson 1988). Iconic hyperlinks used on e-commerce web sites were studied in chapter 6. Many icons being used commercial web sites did not convey the intended meanings to users. Identifiability was emphasized since not identifiable icons cannot be an appropriate hyperlink. Carelessly designed icons can increase the vagueness.

When designing web sites, usability is very important as previous studies showed (Helander 2000, Lohse and Spiller 1998). The results found in this research can be usefully used to design e-business web sites. Chapter 3 can help web designers to design the basic scheme of web sites, chapter 2 and 4 could be used to design better input tools, and chapter 6 would be referred to select and utilize better visual icons on web sites. Researchers can extend the results of chapter 5 to understand and develop menus used for user interface.

Interaction models for various menu, icon, and input tools will be studied in the future to make user interface more usable.

REFERENCES

Egido, C., & Patterson, J. (1988). Pictures and category labels as navigational aids for catalog browsing. *Proceedings of CHI '88 Conference on Human Factors in Computing Systems*, 127-132. ACM, New York

Helander, M. G. (2000). Theories and models of electronic commerce. *Proceedings of the IEA 2000/HFES 2000 Congress*, 2, 770-773.

Howell, W. C. & Fuchs, A. H. (1968). Population stereotypy in code design. *Organization Behavior and Human Performance*, 3, 310-339.

Lodding, K. N. (1983). Iconic interfacing, *IEEE Computer Graphics and Applications*, 3 (2), 11-12.

Lohse, G. L. & Spiller, P. (1998). Quantifying the effect of user interface design features on cyberstore traffic and sales, *Proceedings of CHI '98 Conference on Human Factors in Computing Systems*, 211-218, ACM, New York

Somberg. B. J. (2000). Procedural consistency in the user interface, *Proceedings of the IEA*

2000/HFES 2000 Congress, 307-310.

Rohr, G. (1984). Understanding visual symbols, In IEEE Computer Society (Ed.). *Proceedings of IEEE 1984 workshop on visual Languages*, 184-191, Silver Spring: IEEE Computers Society.

Rohr, G. & Keppel, E. (1984). Iconic interfaces: where to use and how to construct?, In H.W. Hendrick and O. Brown, Jr. (Ed.). *Human Factors in Organizational Design and Management*, 269-275.

APPENDIX. INFORMED CONSENT DOCUMENT

Title of Study: Human-Computer Interaction in E-Business
Investigators: Hong-In Cheng (hicheng@iastate.edu) and Dr. Patrick E. Patterson (ppatters@iastate.edu)

This is a research study. Please take your time in deciding if you would like to participate. Please feel free to ask questions at any time.

INTRODUCTION

The purpose of this study is to examine characteristics of subjects' responses to e-commerce web sites. The web sites include hotel room reservation, menu search and selection. You are being invited to participate in this study because you take an IMSE course.

DESCRIPTION OF PROCEDURES

If you agree to participate in this study, your participation will last for a single day. During the study you may expect the following study procedures to be followed. You will be asked to reserve a hotel room on the experimental web sites and select predetermined options using the programmed menus. After the simulation you will be asked to complete the questionnaire.

RISKS

While participating in this study you may experience the following risks: there are no foreseeable risks at this time from participating in this study.

BENEFITS

If you decide to participate in this study there may be no direct benefit to you. It is hoped that the information gained in this study will benefit society by contributing to an improved understanding of human factors in e-commerce. The knowledge learned could be applied to designing successful e-business web sites.

PARTICIPANT RIGHTS

Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time. If you decide to not participate in the study or leave the study early, it will not result in any penalty or loss of benefits to which you are otherwise entitled

RESEARCH INJURY

Emergency treatment of any injuries that may occur as a direct result of participation in this research is available at the Iowa State University Thomas B. Thielen Student Health Center, and/or referred to Mary Greeley Medical Center or another physician or medical facility at the location of the research activity. Compensation for any injuries will be paid if it is determined under the Iowa Tort Claims Act, Chapter 669 Iowa Code. Claims for compensation should be submitted on approved forms to the State Appeals Board and are available from the Iowa State University Office of Risk Management and Insurance.

CONFIDENTIALITY
Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis. These records may contain private information.

To ensure confidentiality to the extent permitted by law, the following measures will be taken. Subjects will be assigned a unique code and letter and will be used on forms instead of their name. If the results are published, your identity will remain confidential.

QUESTIONS OR PROBLEMS
You are encouraged to ask questions at any time during this study. For further information about the study contact Hong-In Cheng (hicheng@iastate.edu) or Dr. Patrick E. Patterson (ppatters@iastate.edu). If you have any questions about the rights of research subjects or research-related injury, please contact the Human Subjects Research Office, 16 Pearson Hall, (515) 294-4566; meldrem@iastate.edu or the Research Compliance Officer, Office of Research Compliance, 2810 Beardshear Hall, (515) 294-3115; dament@iastate.edu

****

SUBJECT SIGNATURE
Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily answered. You will receive a copy of the signed and dated written informed consent prior to your participation in the study.

Subject's Name (printed) _____

_____ _____
(Subject's Signature) (Date)

INVESTIGATOR STATEMENT
I certify that the participant has been given adequate time to read and learn about the study and all of their questions have been answered. It is my opinion that the participant understands the purpose, risks, benefits and the procedures that will be followed in this study and has voluntarily agreed to participate.

_____ _____
(Signature of Person Obtaining Informed Consent) (Date)