
Determinants of User Acceptance of Digital Libraries: An Empirical Examination of Individual Differences and System Characteristics

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ABSTRACT: The explosion in Internet usage and huge government funding initiatives in digital libraries have drawn attention to research on digital libraries. Whereas the traditional focus of digital library research has been on the technological development, there is now a call for user-focused research. Although millions of dollars have been spent on building "usable" systems, research on digital libraries has shown that potential users may not use the systems in spite of their availability. There is a need for research to identify the factors that determine users' adoption of digital libraries. Using the technology acceptance model (TAM) as a theoretical framework, this study investigates the effect of a set of individual differences (computer self-efficacy and knowledge of search domain) and system characteristics (relevance, terminology, and screen design) on intention to use digital libraries. Based on a sample of 585 users of a university's award-winning digital library, the results strongly support the utilization of TAM in predicting users' intention to adopt digital libraries, and demonstrate the effects of critical external variables on behavior intention through perceived ease of use and perceived usefulness. All of the individual differences and system characteristics have significant effects on perceived ease of use of digital libraries. In addition, relevance has the strongest effect on perceived usefulness of digital libraries.

KEY WORDS AND PHRASES: computer self-efficacy, digital libraries, individual differences, information technology acceptance, technology acceptance model.

RESEARCH AND DEVELOPMENT IN DIGITAL LIBRARIES have grown rapidly in the 1990s [1, 16]. The passion was jointly triggered by the multimillion dollar initiatives launched in 1993 by the U.S. government on digital library projects and the exploding growth in accessibility and utilization of the Internet worldwide [36]. Special journal issues on digital libraries began to appear [36, 63], digital library conferences and workshops were held (ACM Conference on Digital Libraries, Research and Advanced Technology for Digital Libraries: European Conferences, IEEE ADL), and new print and online journals on digital libraries were started [16]. In the United States, the six major digital libraries research projects are: Project Alexandria (University of California, Santa Barbara), Infomedia (Carnegie Mellon University), Stanford Digital Library (Stanford), Digital Library Initiative (University of Illinois), Digital Library Project (University of California, Berkeley), and Digital Library Project (University of Michigan).

Due to their interdisciplinary nature, definitions of digital libraries are abundant [14, 16, 36, 58, 64]. According to Fox et al. [36], the phrase "digital library" means different things to different people. Here, we adopt a research-oriented perspective,

and view a digital library as a "convenient and familiar shorthand to refer to electronic collections and conveys a sense of richer content and fuller capabilities than do terms such as database or information retrieval system" [16, p. 231]. The major advantages of digital libraries as compared to paper libraries include: (1) resources stored in digital form, which are easier to keep track of, (2) remote, fast, and fair access to digital library collections, and (3) techniques for searching offer increased flexibility and power to users [11, 89]. The National Science Foundation [71] in the United States further pointed out that information sources accessed via the Internet are major ingredients of digital libraries.

As online access to documents is becoming more and more popular, the emergence of digital libraries has brought fundamental changes to the library industry with calls for additional research involving various disciplines [25, 32]. The traditional focus of library and information science research on digital libraries ranged from the "hard" side, such as information retrieval and access [13], and system integration [2], to the "soft" side, such as social informatics [14] and copyright management issues [9]. However, more and more library and information science researchers believe that the future avenues of digital libraries research would involve the interaction between the users and the systems [26, 33, 68, 89]. So far, a number of in-depth case studies of individual digital libraries, such as the Alexandria Digital Library [43, 44], Florida Centre for Library Automation [62], Library of Congress's National Digital Library [66], and Project Envision [37], have been conducted. However, these prior studies mainly focused on the implementation of specific technical features of a particular digital library. There is a lack of research that examines the systems from the users' perspective. Furthermore, previous research showed that despite all the efforts aimed at developing "usable" digital libraries to provide better and easier access to a vast amount of electronic collections, these digital libraries could easily remain unnoticed by students, or were seriously underused in spite of their availability [40, 46]. Therefore, there is a need to understand users' acceptance of digital libraries and identify the factors that can influence their intention to use digital libraries.

The technology acceptance model (TAM) is an established model in explaining IS adoption behavior [27, 29]. According to TAM, adoption behavior is determined by the intention to use a particular system, which in turn is determined by perceived usefulness and perceived ease of use of the system. One key benefit of using TAM to understand system usage behavior is that it provides a framework to investigate the effects of external variables on system usage. The potential of utilizing Ajzen and Fishbein's [7] theory in library and information science research has been recognized by some digital library researchers [88]. However, there has been no such empirical research to our knowledge. Therefore, the objective of this study is to identify critical external variables that have significant effects through the TAM framework on potential users' intention to use digital libraries. By explaining usage intention from both users' and systems' perspectives, the findings of this research will not only help universities' authorities to build better "user-accepted" digital libraries, but also provide insights into how to prepare potential users for the new information technologies (IT).

Background

Technology Acceptance Model

BASED ON THEORIES IN SOCIAL PSYCHOLOGY, such as the theory of reasoned action (TRA) [7] and the theory of planned behavior (TPB) [6], the TAM has been validated as a powerful and parsimonious framework to explain users' adoption of IT [27, 29]. According to TAM, usage of an information system is determined by users' intention to use the system, which in turn is determined by users' beliefs about the system. There are two kinds of salient beliefs involved: perceived usefulness and perceived ease of use of the system. Perceived usefulness is defined as the extent to which a person believes that using the system will enhance his job performance. Perceived ease of use is defined as the extent to which a person believes that using the system will be free of effort. Although perceived usefulness has a direct effect on adoption intention, perceived ease of use has both a direct effect and an indirect effect on intention through perceived usefulness. Furthermore, both types of beliefs are subjected to the influence of external variables. By manipulating these external variables, system developers can have a better control over users' beliefs of the system, and subsequently, their behavioral intentions and usage of the system.

When compared to other theoretical models aimed at understanding IS adoption behavior, TAM has been found to have similar or better explanatory power than more sophisticated models, such as TRA and TPB [29, 69, 81]. TAM has been applied to a wide range of IS [e.g., 51, 86], organizational contexts [e.g., 50, 86], and user profiles [e.g., 47, 83]. Despite the large body of existing research on TAM, continuing research efforts in extending TAM can be observed [e.g., 84, 86, 87]. According to Hartwick and Barki [42], it is imperative to examine the acceptance of new technologies with different user populations in different organizational context.

A digital library is different from the IS that have been examined in prior TAM studies in several ways. Whereas most of the prior studies have investigated relatively simple IT, such as personal computer, e-mail system, and word processing and spreadsheet software, the concept of a digital library is much broader in nature. It includes not only the enabling technology, but also the content, services, architecture, distributed environments, and even institutions. The target user group of a digital library is usually a community involving a large number of users, who have more diversified education and socioeconomic background than the user groups that have been studied previously. Furthermore, as an Internet-based technology, the usage context of a digital library is quite different from that of the stand-alone application software. Users can access a digital library from anywhere, and at any time, with complete freedom. Due to the uniqueness of a digital library, it is imperative to examine the acceptance of this complex new technology by its varied community in its special organizational context. Considering both the effectiveness and simplicity of TAM, and its wide applicability to different kinds of IT, we feel confident here to use TAM as a theoretical framework to examine the factors that can affect users' adoption of a digital library.

Previous research on TAM has identified two main categories of external variables, namely, individual differences and system characteristics. Based on the theoretical framework proposed by Zmud [91], individual differences were believed to be most relevant to IS success. Nelson [72] also identified the importance of individual difference variables in affecting new technology acceptance. Empirical research has also found significant relationships between individual differences and IT acceptance via TAM [4, 49, 51, 84]. Similarly, it is believed that human computer interaction research can benefit from incorporating individual differences into the system design [30]. Despite the large body of theoretical and empirical support, Chen et al. [20] called for caution when applying the findings developed for the earlier generations of IS to the new virtual environment. Specifically, they argued that "the effects of individual differences on the use of these new technologies are yet to be found out" [20, p. 499]. Therefore, it is imperative to examine the effects of individual differences in the new context of digital libraries.

System characteristics are recognized as another category of external variables that are capable of influencing users' intention to adopt new IS. Davis et al. [29] proposed that objective design characteristics of a system can have direct effects on perceived usefulness in addition to indirect effects via perceived ease of use. Prior research on TAM supports this argument by showing that system characteristics can significantly affect the intention to use IS via both beliefs from the users [49, 85]. In the field of library and information science, specific system features are also believed to be critical in affecting the usage of digital libraries [37, 56, 57, 74]. However, the processes by which acceptance of digital libraries will be influenced by various system characteristics are not clear. Therefore, this paper will help to clarify the processes by incorporating system characteristics as external variables of TAM.

The Open University of Hong Kong's E-Library

The Open University of Hong Kong (OUHK) is the first university offering open access and distance learning education in Hong Kong. It recruits adult students who attend courses only on a part-time and off-campus basis. In 2000, it had about 25,000 students, the majority of whom were from 26 to 40 years old, with diverse background and occupations. Differing from the traditional undergraduate students, these nontraditional students can be characterized as older, more responsive and motivated, and more heavily pressured by the conflicting demands of home, work, and school [40]. The number of such nontraditional students, who are usually working adults or women with children, is increasing rapidly, due to the availability of more advanced technology for distance learning.

In order to provide the adult students with more resources, as well as better access to distance learning materials, the OUHK launched a digital library, called E-library. As the first and largest of its kind among distance education institutions in Asia, the HK\$40 million (US\$1 = HK\$7.80) digital library in the OUHK maintains 1,000 electronic databases, various e-journals, dictionaries, handbooks, and encyclopedias, library catalogues of local and overseas higher education institutions, and special

indices linking to 40 distance-learning organizations throughout the world (see Figure 1 for an overview). Through these bilingual, Web-based, and full-text library services, students of the OUHK have easy access, from wherever they are, to data equivalent to over 500,000 volumes of publications around-the-clock. In June 2000, the E-library won the Stockholm Challenge Award for its structural innovation in the development of distance learning. As one of the world's most fascinating awards for IT projects, the Stockholm Challenge Award attracted 612 entries worldwide, and the digital library of the OUHK won its award in the education category.

After investing many resources in building the system and improving its functions, it is critical to learn whether the OUHK's nontraditional students are making use of the E-library. As an ongoing project, the digital library is under continuous development. The OUHK is also looking into the prospect of extending the digital library service to a wider learning community other than its own students, including the public. Hence, the OUHK is eager to learn how users feel about the digital library, and more important, what the factors that will influence intention to use the digital library are. In order to do so, we utilize TAM as a theoretical framework to understand the nontraditional students' intention to use the digital library at the OUHK. We also extend TAM to incorporate critical external variables, specifically individual differences and system characteristics, and examine their effect on users' intention through beliefs about the digital library.

Research Model and Hypotheses

PREVIOUS RESEARCH HAS IDENTIFIED TWO MAIN CATEGORIES of external variables, namely, individual differences and system characteristics as major external variables of TAM [4, 28, 49, 51, 84]. The proposed research model includes two individual differences variables and three system characteristics (see Figure 2), the selection of which are supported by prior studies in the IS or library science literature.

Individual Differences

Individual differences are believed to be most relevant to both IS success [41, 91] and human computer interaction research [30]. In a comprehensive review of individual adjustment to IT innovations, Nelson [72] noted that the success of such innovations depends as much on individuals as on the technology itself. In virtual environments, individual differences have been suggested to be related to usage and success of information retrieval systems and online library systems [15, 20]. Interest is growing in user behavior studies as an essential part of the successful development of digital libraries [57, 89]. In a longitudinal study of academic usage of a digital library, Barry and Squires [12] advocated a shift from evaluating how useful a piece of technology is by itself, to evaluating its usefulness from a user's perspective. In this study, we will examine two individual differences variables, computer self-efficacy and knowledge of search domain, which have been found to be important in the IS and library sci-

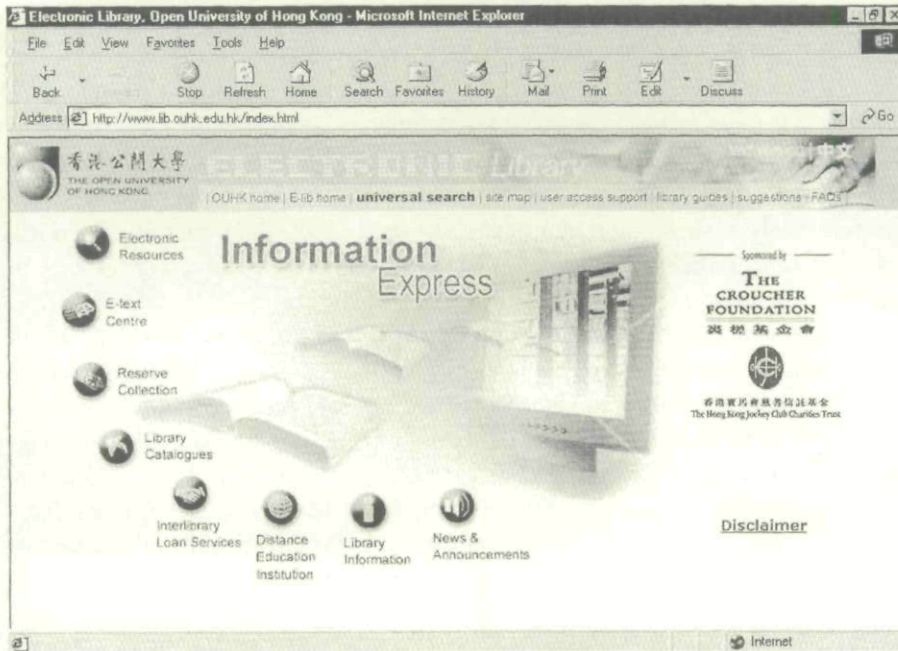


Figure 1. E-Library in the OUHK

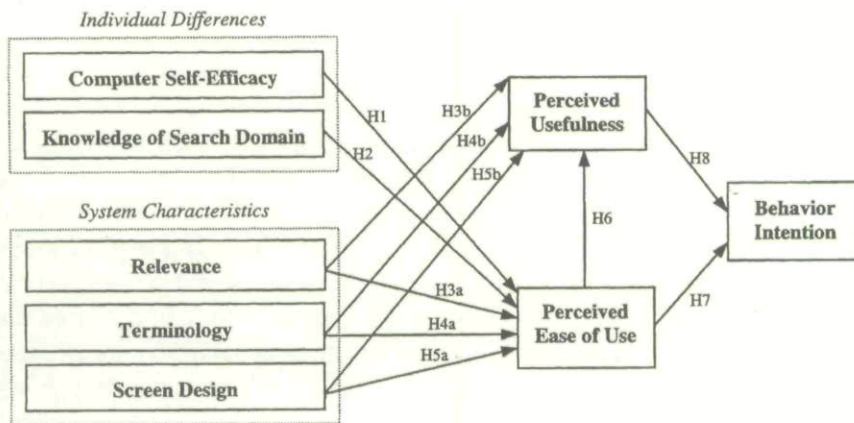


Figure 2. Research Model

ence literature. These two variables were selected because they have frequently been mentioned to be pertinent to the digital library context.

Computer Self-Efficacy

In the library science literature, some researchers have suggested the possible effect of computer literacy on increasing usage of information retrieval systems [8, 26, 52].

However, the mechanism through which this construct affects intention is unclear, and there has been limited empirical research. On the other hand, a related construct, called computer self-efficacy, has been examined in the IS literature. Computer self-efficacy is defined as the judgment of one's ability to use a computer [22]. Grounded in social cognitive theory, computer self-efficacy has been found to be an important predictor of IT usage [22, 23, 45]. Continuing research efforts on computer self-efficacy can be observed in recent IS studies [e.g., 5, 55], which confirm the critical role that computer self-efficacy plays in understanding individual responses to computing technology.

The proposed relationship between computer self-efficacy and perceived ease of use is based on the theoretical argument by Davis [27] and Mathieson [69]. Davis [27] developed the concept of perceived ease of use and perceived usefulness based on self-efficacy theory. He recognized that self-efficacy, which is defined as judgments of how well one can execute courses of action required to deal with prospective situations, is related to perceived ease of use. On the other hand, perceived usefulness is similar to judgment of outcomes. Mathieson [69] further noted that there are two types of control factors suggested by Ajzen's [6] theory of planned behavior: the internal control factors, which include skill and willpower, and the external control factors, which include time, opportunity, and cooperation of others. Whereas the external control issues are not considered in TAM, "EOU (ease of use) corresponds to the internal control factor of skill" [69, p. 179]. Therefore, there is theoretical support that computer self-efficacy, as an internal control factor of skill, will directly affect perceived ease of use of digital libraries.

There also exists empirical evidence of the causal link between computer self-efficacy and perceived ease of use. Venkatesh and Davis [85] found that computer self-efficacy significantly influences perceived ease of use of microcomputers both before and after hands-on experience. Igbaria and Iivari [48] demonstrated that computer self-efficacy has a direct effect on perceived ease of use, but not on perceived usefulness. A similar data pattern was observed by Venkatesh [84] in a variety of information system settings. Consistent with the findings of prior research, Agarwal et al.'s [5] study also found computer self-efficacy to be a key antecedent of perceived ease of use. Therefore, based on the theoretical and empirical support from the IS literature, we hypothesize that computer self-efficacy will have a positive effect on perceived ease of use of the digital library.¹

H1: Computer self-efficacy will have a positive effect on perceived ease of use of the digital library.

Knowledge of Search Domain

Knowledge of search domain is another internal control factor that may positively affect perceived ease of use of digital libraries. Research on information retrieval systems indicates that domain knowledge can support more efficient search by helping users to separate relevant information from irrelevant responses, facilitating learning

of search principles, and formulating more accurate queries [60, 67, 70]. In the virtual environment of digital libraries, unlike in a physical environment where end-user support or managerial support is generally available, there is no one for the user to consult. Under such conditions, the users' background knowledge of search domain can support easier interaction with digital libraries immensely. Therefore, we hypothesize that knowledge of search domain will have a positive effect on perceived ease of use of the digital library.²

H2: Knowledge of search domain will have a positive effect on perceived ease of use of the digital library.

System Characteristics

System characteristics have the potential to directly affect both perceived ease of use and perceived usefulness of IS [29]. Studies that included system features as external variables of TAM have found significant relationships between the system variables and the TAM's beliefs constructs [28, 49, 85, 86]. However, these studies either used a dummy variable to represent different IS [28, 85] or adopted a single overall construct, such as perceived system quality [49] or output quality [86], to substitute for the system characteristics. These simplistic operationalizations do not highlight the effects of individual system characteristics on user acceptance. Therefore, there is a need to identify specific system characteristics and examine their individual effects on both perceived ease of use and perceived usefulness of digital libraries.

The relationships between various system characteristics and the beliefs constructs in TAM can be examined via the usability construct. Instead of examining the ease of use or usefulness, library science researchers have focused on the usability of digital libraries [e.g., 11, 37, 57, 74]. Usability is defined as how *easily* and how *effectively* a computer system can be used by a specific set of users [77]. These two components of usability bear a close resemblance to the perceived ease of use and perceived usefulness constructs in TAM. Hence, the above definition provides us with the basis to examine the effect of various factors of system usability on the beliefs constructs in TAM. Based on Lindgaard's [61] categories of usability factors, we propose three system characteristics as critical external determinants of TAM. Each of them is elaborated on below. They were selected because they have frequently been mentioned in the library science literature of their pertinence to the digital library context (such as, relevance, terminology, and screen design are inherent in information retrieval systems) and the level of control afforded to the digital library designers. Response time, another system characteristic, was not included in this study because digital library designers have little control over it with users connecting to the system through the Internet.

Relevance

Relevance is the degree to which the system matches tasks as carried out in the current environment and as specified in the task analysis [61]. In the context of digital

libraries, it can be interpreted as the degree to which the digital library matches users' information needs [76]. Traditionally, recall (the ratio of relevant items retrieved to all relevant documents in the system) and precision (the ratio of relevant retrieved items to all retrieved items) have been the principle measures of the effectiveness of information retrieval systems [79]. Both of these measures are based on the concept of relevance. More and more library science researchers have started to recognize the importance of user-based relevance judgments in evaluating the effectiveness of information retrieval systems [53, 75, 78]. Gluck [38] found that users' satisfaction with retrieved items is related to the relevance of those items in resolving their information needs. Yao [90] linked relevance with usefulness by arguing that a document is useful only if the user considers the document to be relevant.³ Moreover, when a digital library contains a large amount of relevant information that a user is searching for, it will be easier for her to find the information she needs. Subsequently, the user may interpret the system as easy to use as compared to a digital library where there is little relevant information inside. Therefore, we hypothesize that relevance of the system's content to users' information needs is positively related to both perceived ease of use and perceived usefulness of the digital library.

H3a: Relevance of the system will have a positive effect on perceived ease of use of the digital library.

H3b: Relevance of the system will have a positive effect on perceived usefulness of the digital library.

Terminology

Terminology refers to the words, sentences, and abbreviations used by a system [61]. As an information retrieval system, the issue of terminology is inherent in the success of a digital library. On one hand, users need to submit their queries to the system through structured phrases where knowledge of the terminology used by the system is indispensable. On the other hand, it is also important that users understand the descriptions, instructions, and search results of the digital library clearly and correctly. One major problem with terminology for an information system is inappropriately used jargons. As noted by Talja et al. [80], the vocabulary that users use to express their information needs often differs from the terminology of the information providers. This difference will not only make it difficult for the users to interact with the system, but also decrease the potential benefits that the digital library can provide to the users. Specific efforts have been made to avoid such problems [21]. Terminology has also been identified as a unique factor in users' evaluation of the Alexandria Digital Library project [44]. Therefore, we hypothesize that terminology clarity will have a positive effect on perceived ease of use and perceived usefulness of the digital library.

H4a: Terminology clarity of the system will have a positive effect on perceived ease of use of the digital library.

H4b: Terminology clarity of the system will have a positive effect on perceived usefulness of the digital library.

Screen Design

Screen design is the way information is presented on the screen [61]. It has long been recognized by IS researchers that the interface design and information presentation mode of an information system can greatly influence end users' search strategies and performance [54, 59, 82]. In studies of information retrieval systems, the user interface was reported as equally important as a retrieval engine in affecting system performance [66, 70]. As reported at the Advances in Digital Libraries '97—the IEEE Forum on Research and Technology—interface design matters a great deal [33]. A good screen design can create a comfortable virtual environment where users can easily identify functional groups and navigation aids, freely move around and scan search results, and make more efficient searches. Therefore, we expect screen design to have a positive effect on perceived ease of use and perceived usefulness of the digital library.

H5a: Screen design of the system will have a positive effect on perceived ease of use of the digital library.

H5b: Screen design of the system will have a positive effect on perceived usefulness of the digital library.

Perceived Ease of Use

Extensive research over the past decade provides evidence of the significant effect of perceived ease of use on intention, either directly or indirectly through its effect on perceived usefulness [4, 29, 47, 51, 83, 84, 85, 86, 87]. As a complex information system, a digital library can be avoided, even by talented computer scientists, if it is clumsy and difficult to handle [56]. In order to prevent the "underused" useful system problem, digital libraries need to be both easy to learn and easy to use. Hence, we hypothesize that perceived ease of use of the digital library will have a positive effect on both perceived usefulness and behavior intention to use the digital library.

H6: Perceived ease of use will have a positive effect on perceived usefulness of the digital library.

H7: Perceived ease of use will have a positive effect on behavior intention to use the digital library.

Perceived Usefulness

Users' intention to use an information system is driven, to a large extent, by their perceived usefulness of the system [29]. There is also extensive empirical evidence in

the IS literature [4, 29, 47, 51, 83, 84, 85, 86, 87]. The ultimate reason that users exploit digital libraries is that they find the systems useful to their information needs or search tasks. Therefore, we hypothesize that perceived usefulness will have a positive effect on behavioral intention to use the digital library.

H8: Perceived usefulness will have a positive effect on behavior intention to use the digital library.

Research Methodology

Sample

TARGET RESPONDENTS WERE STUDENTS OF THE OUHK. A representative cross-section of the student population was included in the interview sample. To assure that the beliefs measured were formed based on direct behavior experience with the object [28], only responses from those who had previously used the digital library were included. Out of 1,244 interviews conducted, 585 interviews of those with experience of the system were retained for data analysis. Among them, about one-third of the interviewees had not used the digital library in the past three months. This would increase the external validity of this study because the research findings were not biased toward enthusiastic system users.

Data Collection Procedure

A telephone interview method was employed for the survey. Respondents were screened for whether they had ever used the E-library. Only those who had previously used the E-library continued with the interview. The interviews were conducted over a period of two weeks by a team of 15 interviewers. All interviewers had prior experience in conducting telephone interviews. They had also participated in role-playing exercises prior to the actual interviewing. A standard interview protocol was utilized by all interviewers. To ensure the quality of the interview sessions, fieldwork was carried out under supervision. Field supervisors conducted checks on each completed interview and took immediate actions, such as recalling subjects for the verification of ambiguous answers, on discovering any problem. On average, it took 17 minutes to interview those with experience of the digital library.

Measures

One advantage of using TAM to examine digital library acceptance is that it has a well-validated measurement inventory [3, 27, 31]. Perceived ease of use and perceived usefulness were measured by four items each, from the previously validated inventory and modified to suit the current context (see Appendix). The items to measure behavior intention were taken from previous applications of TAM [4, 85].

As a multilevel and multifaceted construct, the psychometric properties of computer self-efficacy are not easy to capture [65]. We decided to use the instrument developed by Compeau and Higgins [22], which has been empirically validated in other studies [22, 23, 55, 85]. Knowledge of search domain was assessed by two items suggested by Davies [26]: familiarity with the chosen subject domain and knowledge of the topic to search. Items for measuring the three system characteristics were taken from the Alexandria Digital Library's user survey [43], and were rephrased for the OUHK's E-library. Likert scales (1~7), with anchors ranging from "strongly disagree" to "strongly agree," were used for all questions except for the items measuring computer self-efficacy. The anchors of the items measuring computer self-efficacy ranged from "not at all confident" to "totally confident."

Data Analysis and Findings

Instrument Validation

A CONFIRMATORY FACTOR ANALYSIS USING LISREL 8 was conducted to test the measurement model. The fit of the overall measurement model was estimated by various indices provided by LISREL (see Table 1). χ^2 statistic was not used because of its sensitivity to large sample size. Instead, the ratio of χ^2 to degrees-of-freedom (df) was used, and a value of 2.64 was obtained, which is within the suggested value of 3 [18]. Also note the goodness-of-fit (GFI) and adjusted goodness-of-fit (AGFI) were 0.91 and 0.89, respectively. The normalized fit index (NFI), non-normalized fit index (NNFI), and comparative fit index (CFI) are three other indices of fit. Values typically range from 0 to 1, with values greater than 0.9 representing reasonable model fit. For the measurement model, we observed values of 0.93, 0.95, and 0.96 for NFI, NNFI, and CFI, respectively, all indicating good model fit. Finally, root mean square residual (RMSR) provides an indication of the proportion of the variance not explained by the model, whereas root mean square error of approximation (RMSEA) describes the discrepancy between the proposed model and the population covariance matrix. Both values were 0.05, which was within the recommended cutoff values of 0.10 (RMSR) and 0.08 (RMSEA) for good fit [17]. Therefore, we could proceed to evaluate the psychometric properties of the instrument in terms of reliability, convergent validity, and discriminant validity.

Reliability and convergent validity of the constructs were estimated by Cronbach's alpha, composite reliability, and average variance extracted (see Table 2). Cronbach's alphas for all constructs were above the 0.70 threshold for field research and above 0.80 for all TAM constructs [73]. The composite reliabilities produced very similar results. The average extracted variances were all above the recommended 0.50 level [39], which meant that more than one-half of the variances observed in the items were accounted for by their hypothesized constructs. Convergent validity can also be assessed by factor loadings and squared multiple correlations from the confirmatory factor analysis (see Table 3). Following Hair et al.'s [39] recommendation, factor loadings greater than 0.50 were considered to be very significant. A stricter criterion

Table 1. Fit Indices for Measurement and Structural Models

Fit Indices	Recommended value	Measurement model	Structural model
χ^2	N/A	714.61	729.31
df	N/A	271.00	278.00
χ^2/df	≤ 3.00	2.64	2.62
Goodness-of-fit (GFI)	≥ 0.90	0.91	0.91
Adjusted goodness-of-fit (AGFI)	≥ 0.80	0.89	0.89
Normalized fit index (NFI)	≥ 0.90	0.93	0.93
Non-normalized fit index (NNFI)	≥ 0.90	0.95	0.95
Comparative fit index (CFI)	≥ 0.90	0.96	0.95
Root mean square residual (RMSR)	≤ 0.10	0.05	0.06
Root mean square error of approximation (RMSEA)	≤ 0.08	0.05	0.05

Note: N/A means not applicable.

of loading greater than 0.70 was proposed by Fornell [34]. All of the factor loadings of the items in the research model were greater than 0.50, with most of them above 0.70. Each item loaded significantly ($p < 0.01$ in all cases) on its underlying construct. Also, squared multiple correlations between the individual items and their *a priori* constructs were high (above 0.40 in all cases). Therefore, all constructs in the model had adequate reliability and convergent validity.

To examine discriminant validity, we compared the shared variances between constructs with the average variance extracted of the individual constructs [35]. This analysis shows that the shared variance between constructs were lower than the average variance extracted of the individual constructs, confirming discriminant validity (see Table 4). In summary, the measurement model demonstrated adequate reliability, convergent validity, and discriminant validity.

Structural Model

A similar set of fit indices was used to examine the structural model (see Table 1). The ratio of χ^2 to degrees-of-freedom was 2.62 for the structural model, again within the recommended level of 3. Comparison of other fit indices with their corresponding recommended values provided evidence of a good model fit (GFI = 0.91, AGFI = 0.89, NFI = 0.93, NNFI = 0.95, CFI = 0.95, RMSR = 0.06, RMSEA = 0.05). Therefore, we could proceed to examine the path coefficients of the structural model.

Properties of the casual paths, including path coefficients, *t*-values, and variance explained for each equation in the hypothesized model are presented in Table 5. As expected, hypotheses H7 and H8 were supported in that both perceived ease of use and perceived usefulness had a significant positive effect on behavior intention. Altogether, they accounted for 52 percent of the variance in behavior intention with perceived usefulness ($\beta = 0.51$) contributing more to intention than perceived ease of use

Table 2. Descriptive Statistics of Constructs

	Mean	Standard deviation	Cronbach's alpha	Composite reliability	Average variance extracted
Computer self-efficacy	5.47	0.91	0.89	0.89	0.51
Knowledge of search domain	4.06	1.30	0.85	0.85	0.73
Relevance	4.13	1.18	0.80	0.80	0.66
Terminology	4.79	1.07	0.77	0.77	0.62
Screen design	4.69	1.06	0.86	0.86	0.76
Perceived ease of use	4.76	1.02	0.90	0.91	0.71
Perceived usefulness	4.37	1.22	0.94	0.94	0.81
Behavior intention	4.95	1.19	0.80	0.80	0.66

Table 3. Descriptive Statistics of Items

	Mean	Standard deviation	Factor loadings	Squared multiple correlations
Computer self-efficacy				
CSE1	4.01	1.43	0.72	0.53
CSE2	5.14	1.37	0.78	0.60
CSE3	5.31	1.28	0.80	0.64
CSE4	5.87	1.15	0.66	0.43
CSE5	5.82	1.16	0.65	0.42
CSE6	5.80	1.12	0.69	0.48
CSE7	5.67	1.17	0.72	0.52
CSE8	6.16	0.99	0.65	0.42
Knowledge of search domain				
KSD1	4.17	1.42	0.89	0.80
KSD2	3.95	1.37	0.82	0.68
Relevance				
Rele1	4.27	1.29	0.81	0.66
Rele2	3.99	1.29	0.82	0.68
Terminology				
Term1	4.91	1.22	0.81	0.66
Term2	4.68	1.15	0.77	0.60
Screen design				
Scre1	4.74	1.13	0.86	0.74
Scre2	4.65	1.12	0.88	0.78
Perceived ease of use				
PEOU1	4.94	1.24	0.83	0.69
PEOU2	4.62	1.08	0.79	0.62
PEOU3	4.68	1.22	0.88	0.77
PEOU4	4.80	1.11	0.86	0.74
Perceived usefulness				
PU1	4.39	1.32	0.91	0.82
PU2	4.21	1.27	0.87	0.76
PU3	4.27	1.38	0.90	0.81
PU4	4.59	1.31	0.91	0.83
Behavior intention				
BI1	5.17	1.28	0.80	0.64
BI2	4.72	1.32	0.83	0.70

Note: Factor loadings are from confirmatory factor analysis.

($\beta = 0.17$). Perceived ease of use also had a positive effect on perceived usefulness ($\beta = 0.39$). Therefore, the total effect of perceived ease of use on behavior intention was $0.37 (= 0.17 + 0.39 * 0.51)$. Even after the indirect effect was accounted for, perceived usefulness still had a stronger explanatory power of the intention to use the digital library than perceived ease of use (0.51 versus 0.37).

As for the paths from the external variables to the TAM constructs, the results were mixed. All five hypotheses concerning the effects of external variables on perceived

Table 4. Discriminant Validity

Construct	1	2	3	4	5	6	7	8
1. Computer self-efficacy	0.51							
2. Knowledge of search domain	0.14	0.73						
3. Relevance	0.04	0.24	0.66					
4. Terminology	0.14	0.41	0.16	0.62				
5. Screen design	0.06	0.30	0.29	0.37	0.76			
6. Perceived ease of use	0.21	0.42	0.28	0.53	0.46	0.71		
7. Perceived usefulness	0.07	0.22	0.49	0.22	0.23	0.37	0.81	
8. Behavior intention	0.06	0.18	0.24	0.24	0.23	0.28	0.50	0.66

Note: Diagonals represent the average variance extracted. Other entries represent the shared variance.

Table 5. Hypotheses Testing

	Beta	<i>t</i> -value	<i>R</i> ²
Perceived ease of use			
= Computer self-efficacy	0.18	5.32***	0.69
+ Knowledge of search domain	0.11	2.66**	
+ Relevance	0.14	3.37***	
+ Terminology	0.37	6.14***	
+ Screen design	0.29	5.58***	
Perceived usefulness			
= Perceived ease of use	0.39	5.01***	0.57
+ Relevance	0.61	10.38***	
+ Terminology	0.07	0.89	
+ Screen design	-0.09	-1.31	
Behavior intention			
= Perceived ease of use	0.17	3.46***	0.52
+ Perceived usefulness	0.51	11.17***	

Note: ** $p < 0.01$; *** $p < 0.001$. Beta: standardized coefficients.

ease of use were supported (H1, H2, H3a, H4a, H5a). Users with higher computer self-efficacy and greater knowledge of search domain found the digital library easier to use. Also, system characteristics, in terms of clear terminology, good screen design, and relevance of the digital library to users' information needs, helped users to interact with the digital library more easily. On the other hand, although relevance was also found to have a large positive effect on perceived usefulness (H3b), the other two system characteristics, terminology and screen design, did not have significant effects on perceived usefulness as hypothesized. Therefore, hypotheses H4b and H5b were not supported. The results of hypotheses testing are also presented in Figure 3, with significant paths depicted by bold lines and insignificant paths by dash lines.

Discussion

TAM Variables

THIS STUDY PROPOSED AND TESTED an extended technology acceptance model in the context of a major digital library. Past research on TAM focused mainly on personal computer usage [49, 50] or simple application software acceptance, such as e-mail, word processing and spreadsheet software, and Windows operating system [4, 19, 28, 29, 31, 69, 85]. This study is a pioneering effort in applying TAM to the newly emerging context of information retrieval systems—digital libraries, which have become available and popular only recently. Moreover, the sample of nontraditional students has more diversity in their background than the student subjects used in most prior studies. This is due to the nature of the organization that we investigated. Unlike other universities where undergraduate or MBA students have similar backgrounds, the

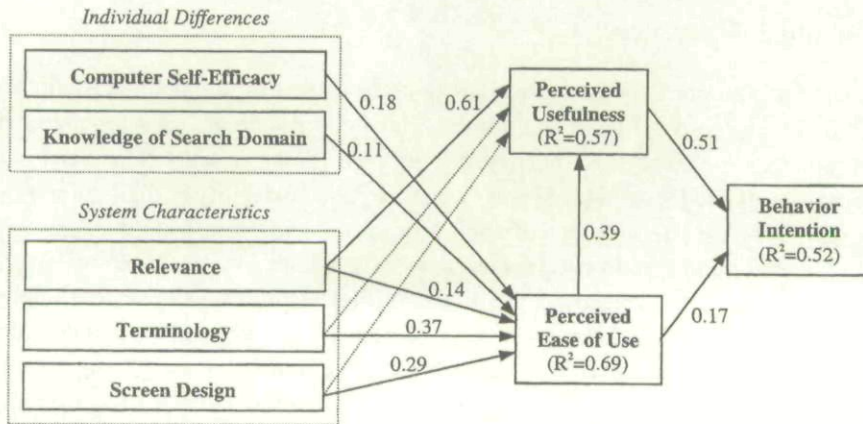


Figure 3. Hypotheses Testing Results

OUHK admits adult students with very different occupational backgrounds. Such a setting will increase the generalizability of the results of this study.

The findings of this study strongly support the appropriateness of using TAM to understand the intention of nontraditional students to use a digital library. The significant effects of both perceived usefulness and perceived ease of use on behavior intention were observed, with perceived usefulness exerting a stronger influence than perceived ease of use. Previous research comparing the relative explanatory power of perceived usefulness and perceived ease of use has generated mixed results. Although a majority of them found perceived usefulness to have a stronger influence [28, 47, 86], others acknowledged the superiority of perceived ease of use over perceived usefulness [3], still others observed a similar level of influence from both beliefs [4, 50].

There are two reasons why perceived usefulness has a stronger effect on behavior intention in the case of this digital library. The first explanation is time. In the early stages of exploring the digital library, perceived ease of use is the major determinant of system use. However, in the later stages of stable usage, when users have accumulated more experience with using the digital library, the significance of perceived ease of use will decrease while the significance of perceived usefulness will increase. Our findings support Davis's [27] contention that perceived ease of use may actually be a causal antecedent to perceived usefulness, as opposed to a parallel, direct determinant of system usage. Digital libraries, which at first seem easy to use, may, in the long run, be abandoned if they do not also provide critically needed functionality.

The second explanation is the characteristics of the user group in this study. The nontraditional students of the OUHK, who are usually under a high degree of time pressure, will only use the digital library if they find it to be useful to their studies. Given that the usage of the digital library is completely voluntary, and the target user group consists of a large number of people with diversified backgrounds, the findings of this study suggest that in order to attract more users to use digital libraries, it is not enough to make the systems easy to interact with. It is of paramount importance to develop digital libraries with useful content and valuable functions for the users.

Individual Differences

Consistent with our hypothesis, users with higher levels of computer self-efficacy will find it easier to use the digital library. This finding supports prior research that has found a significant direct relationship between computer self-efficacy and perceived ease of use [5, 48, 84, 85] and extends its generalizability to digital libraries. By examining the effect of computer self-efficacy on a new information technology, which is more complex in nature than previously studied systems, such as e-mail, word processing, and spreadsheet software, our result further validates the importance of computer self-efficacy in understanding user acceptance of various computing technologies. Users who have higher levels of confidence in using computers in general are more likely to find the digital library easy to use. In order to increase the computer self-efficacy of users, universities' authorities can organize training courses on various computer software to increase familiarity with computing technologies. Even if these courses are not directly related to the digital library itself, they can still help the users to interact with the system more easily.

Knowledge of search domain is another individual difference variable that was found to have a positive effect on perceived ease of use of digital libraries. When users are more familiar with the subject domain they are searching, the search activities become easier for them. This finding supports the recommendation of library science researchers to provide customized interfaces to different individuals [10, 70]. Although library administrators do not have control over the users' general knowledge of the domain they want to search on the digital library, flexible functions can be incorporated into the digital library to adjust for the users' differing degree of search domain knowledge. Nowadays, more and more digital libraries provide different interfaces for "domain experts" and "novice searchers." Novice searchers may have difficulty in generating appropriate query terms and interpreting search results. Therefore, they will prefer a natural language interface where they can form the queries as the questions in their minds. Also, search aids, as well as more detailed information of search results, can greatly help novice users of digital libraries to perform their information search. On the other hand, domain experts are usually more specific about what they are seeking, and will therefore prefer search interfaces where they can enter multiple criteria at the same time to speed up the search process. When interpreting search results, too detailed information may be regarded as unnecessary by domain experts and may even impede their search efficiency. By providing customized interfaces, digital libraries can better accommodate the needs of users with different degrees of search domain knowledge.

System Characteristics

The three system characteristics have different effects on users' beliefs about the digital library. While relevance has a significant effect on both perceived ease of use and perceived usefulness of the digital library, the other two system characteristics, terminology and screen design, only have significant effects on perceived ease of use. The

difference in the effects of these variables provides insight into the nature of these system features. Relevance focuses on the content of the system, whereas terminology and screen design are related to the interface of the digital library.

It is not surprising to find that relevance has a strong effect on perceived usefulness. This is because the purpose of a digital library is to provide relevant documents to the users. It is also worth noting that a recent study by Venkatesh and Davis [86] found that job relevance, a similar construct to relevance used here, has a positive effect on perceived usefulness. The results of these two studies suggest that the fit between the capability of the technology and the need of the users is an important antecedent of perceived usefulness of the technology. In addition, the current study contributes to a more thorough understanding of the relevance construct by identifying a direct link from relevance to perceived ease of use. Having more relevant content in the digital library can assist the users in finding the necessary information more easily. Hence, relevance can change the users' beliefs of their interaction with the system, and subsequently influence their intention to use the digital library.

The two interface-related system characteristics, terminology and screen design, were found to have significant effects on perceived ease of use, but not on perceived usefulness. Previous studies on TAM have operationalized system characteristics as a single overall measure and have found significant effects on both beliefs. The findings in this study, however, suggest that different characteristics of a system can have different effects on perceived ease of use and perceived usefulness. Therefore, future research that wants to study the effect of the system should specify the individual system characteristics and identify their potential effects on perceived ease of use and perceived usefulness. Similarly, although usability includes the concepts of both ease of use and usefulness, the individual usability factors may have their own properties and affect either one or both of the beliefs. Therefore, there is a need to examine the effect of specific system characteristics individually. The fact that the interface-related system characteristics only have significant effects on perceived ease of use of the digital library suggests that users will hardly find the digital library more useful simply because they like its interface. A user-friendly interface can help users to use the digital library more easily, but by itself, will not make the digital library more useful.

Conclusion

THIS RESEARCH IS A RESPONSE TO THE CALL for user-oriented research in digital libraries. Utilizing the well-established technology acceptance model as a theoretical framework, critical external variables, consisting of two individual differences and three system characteristics, were proposed to have significant influence on the intention to use a digital library via perceived usefulness and perceived ease of use. The contributions of this study to technology acceptance research are fourfold. First, it has successfully applied TAM in a new information system context (that is, digital library) that is very different from the systems examined in prior studies. Perceived ease of use and perceived usefulness were found to be significant antecedents of the

intention to use a digital library. Second, both individual differences and system characteristics are important determinants of perceived ease of use of the digital library. Third, relevance, a content-based system characteristic, has a greater effect on perceived usefulness of a digital library than the interface-based system features. Finally, the findings of this study have external validity due to the varied demographics of the OUHK's nontraditional students.

The findings of this study have implications for developing usable digital libraries. Considering the millions of dollars that have been invested in digital libraries worldwide, it is of paramount importance to ensure that students will actually use them. In order to achieve this goal, attention must be placed in designing user-friendly interfaces, including using student-familiar terminology, well-depicted buttons and icons, consistent interface style, and clear navigation flow. At the same time, developers of digital libraries should keep in mind that, although these interface-related system features may appeal to users in the early stages, their final decisions on whether to use a system or not depend on the content of the digital library. Specifically, how relevant the resources in the digital library to their study needs are. Efforts can also be put into providing customized interfaces for different users to accommodate their different background knowledge of the search domains. The universities' administrators can also organize computer training courses to increase the general computer self-efficacy of the students. Students with higher computer self-efficacy will be more able to use the digital library, as well as other IS intended to help them study more effectively.

This research has several limitations. First, we did not incorporate actual usage behavior in the proposed model. However, this is not a serious limitation as there is substantial empirical support for the causal link between intention and behavior [81, 86, 87]. Second, there may be other individual and system variables that may affect the intention to use digital libraries. Future research can incorporate other variables into the research model. Potential individual differences include information-seeking skill and computer anxiety. Prior research has found computer anxiety to be a distinct construct from computer self-efficacy. Some other system usability characteristics suggested by Lindgaard [61] include feedback and redundancies. Future research can examine whether these system characteristics have any influence on the acceptance of digital libraries.

NOTES

1. We do not hypothesize that computer self-efficacy has a direct effect on perceived usefulness due to a lack of theoretical and empirical support. Based on Davis's [27] and Mathieson's [69] arguments, there is only theoretical support for the link between computer self-efficacy and perceived ease of use. Prior studies on TAM have also only hypothesized the link from computer self-efficacy to perceived ease of use. In the only paper [48] that investigated the link between computer self-efficacy and perceived usefulness, it was found to be insignificant.

2. Similarly, we do not hypothesize that knowledge of search domain has an effect on perceived usefulness due to the theoretical arguments by Davis [27] and Mathieson [69]. Knowledge of search domain is an internal control factor that will only affect perceived ease of use.

3. Despite their close relationship, relevance and perceived usefulness are distinct constructs. Library science researchers have called attention to the difference between *relevance* and other related constructs, such as *usefulness* [76] and *utility* [24, 53]. (*Utility* is defined as the degree to which a document is useful to the user who requested it, and is very similar to usefulness.) Based on the theoretical support from the library science literature, we conclude that relevance and perceived usefulness are distinct constructs.

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Appendix

Knowledge of search domain

- KSD1 I am familiar with the subject domain that I search for on the E-library.
 KSD2 I am knowledgeable in the topic to search for on the E-library.

Terminology

- Term1 I understand most of the terms used throughout the E-library.
 Term2 The use of terms throughout the E-library is consistent.

Screen design

- Scre1 The E-library commands are well depicted by buttons and symbols.
 Scre2 The layout of the E-library screens is clear and consistent.

Relevance

- Rele1 The resources in the E-library relate well to my study.
 Rele2 The E-library has enough resources for my study.

Perceived ease of use

- PEOU1 Learning to use the E-library is easy for me.
 PEOU2 My interaction with the E-library is clear and understandable.
 PEOU3 It would be easy for me to become skillful at using the E-library.
 PEOU4 I would find the E-library easy to use.

Perceived usefulness

- PU1 Using the E-library would enable me to accomplish my study more effectively.
 PU2 Using the E-library would improve my performance in my study.
 PU3 Using the E-library would make it easier for me to do my assignments and prepare for the examination.
 PU4 I would find the E-library useful in my study.

Behavior intention

- BI1 Assuming that I have access to the E-library, I intend to use it.
 BI2 I intend to increase my use of the E-library in the future.
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