Experimental Study on the Quantification of Functional User Experience in Library Information Services (Postprint)

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Abstract

[Purpose/Significance] This study selects library websites of two universities and conducts a quantitative empirical study on functional user experience of library information services from a user perspective. Through benchmarking, and combining experimental data with actual conditions, it identifies gaps and discovers problems, thereby proposing feasible suggestions for improving the user experience of library websites.

[Method/Process] The research comprehensively investigates quantitative methods and tools for user experience, focuses on interaction design between users and library websites, and obtains relevant data for each metric through experimental methods and questionnaire surveys, thereby truly reflecting the entire experience process of users participating in library information services.

[Results/Conclusion] Feasible suggestions are proposed for library websites: lay a service foundation and strengthen traditional information services; optimize service processes to avoid repetitive operations; add internal search functionality to highlight service modules; strengthen effective communication to effectively solve user problems; excavate personalized characteristics to provide in-depth services.

Full Text

Preamble

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Experimental Study on Quantifying Functional User Experience of Library Information Services

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Abstract

[**Purpose/Significance**] This study selected library websites from two universities to conduct empirical research on quantifying functional user experience of library information services from a user perspective. Through benchmarking and combining experimental data with actual conditions, the study identifies gaps and problems, and proposes feasible recommendations for improving library website user experience. [**Method/Process**] The research comprehensively examined user experience quantification methods and tools, focusing on interaction design between users and library websites. Data for various metrics were collected through experimental and questionnaire survey methods to authentically reflect users' complete experience processes when participating in library information services. [**Result/Conclusion**] The study proposes feasible suggestions for library websites: strengthen foundational services and traditional information services; optimize service processes to avoid repetitive operations; add internal search functions to highlight service modules; enhance effective communication to genuinely solve user problems; and 挖掘个性特征，提供深度服务.

Keywords: library information services; functional user experience quantification; interaction design
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The quality of library information services is the foundation for sustainable library development. The network environment has brought profound changes to library information services. In the new network technology environment, users' awareness of personalization and participation has increased, and their demands for library information service quality continue to rise. The former library-oriented, single passive service can no longer meet user needs. It is necessary to better embed interaction design into library services, which is not limited to simple browsing and retrieval, but includes interaction design with user participation in decision-making, allowing users to express their ideas through recommendations and consultations. Only in this way can library services be efficiently utilized and truly connect users with library resources. In summary, improving library information service quality through better interaction design and satisfactory user experience is the only way to truly adopt a user-centered perspective and form a virtuous cycle of continuous library website usage.

Previous research has classified library information services, determined experimental variables, and conducted in-depth analysis of measurement methods and standards for each variable as the main quantitative basis for this study. The entire research process, from experimental design to implementation, from data analysis to conclusions, closely revolves around eight tasks covering library information services. Through empirical research methods to quantify user ex-

perience and identify problems, the study proposes practical recommendations for improving library information service quality, making the research more meaningful in practice.

The quantification of functional user experience in library information services must rely on specific library websites. However, due to limitations in library development history, funding, system completeness, technical support, and management permissions, the interactive interfaces presented to users vary across library websites, resulting in different user experiences. Therefore, this paper theoretically focuses on interaction design, interaction methods, and means, drawing on more user experience quantification methods. Through benchmarking, the study adopts a new perspective combining interaction design, user experience quantification, and library information services to conduct empirical research.

2 Literature Review

Regarding quantitative research on user experience, participation from various disciplines has continuously enriched user experience quantification methods. Scholars in psychology, with their unique disciplinary advantages, not only use questionnaires, focus groups, interviews, and field observation methods to obtain user experience data, but also employ electrophysiological techniques (skin conductance, EEG, ECG), sensor technology (skin conductance sensors, EEG sensors), eye-tracking methods, and network behavior detection tools like usertracker to obtain objective reflections of user experience in real time. Additionally, scholars have proposed role-playing experience research, behavior and task-centered experimental methods, two-category methods, MOS, and paired comparison methods, which improve the accuracy of user experience quantification and reduce experimental uncertainty.

The functionality of user experience is reflected to a certain extent in interaction design. Previous scholars have conducted research on library interactive services, library interactive retrieval, interaction design in virtual reference consultation platforms, and interaction design of browsing and retrieval interfaces. However, few studies have explored user experience by connecting services with interfaces. This paper examines library functional information service user experience quantification from a new perspective of interaction design and library information services, which is conducive to improving library information service quality and truly achieving a user-centered approach.

In user experience quantification research, specific metrics involved in various studies are shown in Table 1 , such as trajectory length, entry/exit frequency, session duration, and dwell time in web searches. H.L. O'Brien recorded behavioral data including dwell time, reading and browsing time, and pages visited, as well as physiological response data (HR, EDA, and EMG) from some participants, combining these with users' subjective evaluations for comprehensive user experience research. Wu Xiyuan used user return rate, response speed, naviga-

tion clarity, and correct click rate for quantitative analysis in her research. Some scholars used think-aloud protocols, scoring, and feedback evaluations to collect data. Eye-tracking research measures fixation points through "heat maps" and eye movement paths. In some user experience quantification experiments, task completion rate, number of clicks, errors, and page counts were calculated using traditional statistical methods, followed by questionnaires and interviews. Professor Yin Zhibo's behavior-centered quantification method obtained data on user operation steps, time, and information reception frequency, while using questionnaires to obtain users' subjective experience levels. Previous research provides a strong theoretical foundation for this study in terms of experimental variables, measurements, and experimental design, enhancing the scientific rigor and robustness of the research.

Regarding tools used in user experience quantification research, scholars have provided detailed introductions in literature, such as W3touch, MATE, and RMTS, which can record interaction behaviors on mobile phones and perform not only data collection but also certain automatic analysis. Using Morae Recorder software, experimenters can conduct experimental observations while participants operate the experiment. UsaProxy, WAUTER, and WebQuilt can capture detailed user behaviors such as clicks, drags, and page scrolling.

The objects of interaction design vary among scholars, mainly including interactions between users, information service personnel, information resources, system platforms, and technology. Specifically, some scholars believe library interaction design involves interactions among users, information content, and systems; others consider it as interactions among users, information service personnel, information resources, and system platforms; some view it as interactions among resources, technology, and people; and others support interactions among users, systems, and environments. In summary, interaction design can also be divided into two categories: human-computer interaction and interpersonal interaction. Combined with the classification of library information services mentioned earlier, the author summarizes as shown in Figure 1 [Figure 1: see original paper]. The author believes that the quality of interaction design relates to whether users, interfaces, and services can cooperate to complete interactions in a given environment. In terms of users, factors such as cognition, behavior habits, ability, experience, and background; in terms of interfaces, aspects like complete functionality, reasonable layout of interface elements, and interface feedback; and in terms of services, factors including service location on the interface, service methods, and service efficiency, all affect interactive experience.

During the interaction process, supported by computer technology, interaction methods achieve synchronous real-time and asynchronous delayed interaction across time and space, self-organizing interaction, mobile interaction, and model-building interactions such as menu interaction, question interaction, function key interaction, and voice interaction. In the network environment, interaction means are also diverse, completed through SMS, email, social media, portal

websites, blogs, forums, and other channels (see Table 2).

Through analysis, it is not difficult to find that interaction design always adheres to the user-centered principle. The author categorizes user interaction design according to user interaction behaviors and operation logic from entering to exiting the interface (see Table 3).

In summary, user experience has become a research hotspot, but studying functional aspects—interaction design and interface operation user experience—from the user perspective has not received sufficient attention. The involved research content is not systematic enough, and many proposed experimental methods have not been practiced. This paper focuses on user behavior and feelings, using experimental methods to conduct research on quantifying functional user experience of library information services.

3 Experimental Design and Implementation

3.1 Selection of Experimental Subjects

This study selected the library websites of Tianjin Normal University (hereinafter referred to as University A) and Nankai University (hereinafter referred to as University B) as comparison objects in this experimental research. The reasons are: In terms of services, University B's library integrates "collection, search, borrowing, reading, and reference" functions with management center responsibilities. The library not only has high hardware standards but also continuously expands various forms of innovative services. In addition to traditional services such as paper literature borrowing, multimedia reading, reference consultation, interlibrary loan, document delivery, subject services, sci-tech novelty search, lectures, and exhibitions, the application of intelligent information management systems such as mobile libraries, RFID systems, seat management systems, 3D navigation, self-service borrowing and returning, and self-service printing systems has made library information services comprehensive, with increasingly modernized library standards. In terms of systems, University B's library has introduced the LIBSYS library management system from Huiwen Software Company, further optimizing integrated computer management of all workflow segments and achieving high-speed network connections between libraries for resource sharing. Additionally, University B's library is a member of the China Academic Library & Information System (CALIS) and serves as the literature assurance center for liberal arts and sciences in Tianjin's university digital library construction. The Secretariat of Tianjin University Library and Information Work Committee is also located in this library, making positive contributions to resource sharing in national higher education and digital library construction in Tianjin universities.

Therefore, it is evident that University B's library possesses a relatively high level of information services. Selecting University B's library website allows for comparison with University A's library website to identify gaps in functional user experience.

Regarding experimental participants, this study used convenience sampling to recruit 17 undergraduate and graduate students from University A who were willing to participate in the experiment, striving to cover various disciplines with balanced gender representation. Regarding sample size, this study set a confidence interval to determine what percentage of experimental participants could complete experimental tasks at a 95% confidence level. Therefore, small-sample experiments are also meaningful for this research.

3.2 Experimental Task Design

In the experiment, participants operated both University A's and University B's library websites. For similar service tasks, learning effects might inevitably occur and impact experimental results. This study addressed this issue through balanced methods, arranging the experimental order for University B and University A in advance. Three days before the experiment, participants received training to ensure equal familiarity with both library websites, maintaining experimental rigor.

The experiment adopted a structured approach with clear definitions of task start and end states, and unified and explicit calculation standards and methods for experimental variables and measurements. Based on the classified library information service types and the experimental design above, this study designed eight experimental tasks for each library website:

Task 1: Browsing. Browse University A's library website (http://tsg.tjnu.edu.cn/) and complete the task completion status and Table 1 in the questionnaire.

Task 2: Navigation. Determine which navigation bar "Document Delivery" belongs to, select the answer, and complete Table 2 in the questionnaire.

Task 3: Collection Search (Search Service). Inspired by a case discussed in class, search for the book "Love in the Time of Cholera" in the library website, select its classification number according to the Chinese Library Classification system, and complete Table 3 in the questionnaire.

Task 4: Consultation (Consultation Service). Xiaoming encountered the problem: "Why does it show 'User Not Registered' when I, as an undergraduate of University A, swipe my card for self-service borrowing?" Try your best to solve this problem using various methods. Complete the task completion status and Table 4 in the questionnaire.

Task 5: Recommendation (Recommendation Service). Use your library account (borrowing card number: SD+student ID, password: 111) to complete a new book recommendation and receive feedback from the library (recommended book: "The Wisdom of I Ching" by Zeng Shiqiang, reason: needed by readers but not in library collection). Complete the task completion status and Table 5 in the questionnaire.

Task 6: Lecture Notification (Notification Service). Query the resource

training lecture schedule for the first semester of the 2016-2017 academic year, select the correct lecture time and speaker, and complete Table 6 in the questionnaire after selecting the answer.

Task 7: Interlibrary Loan (Traditional Service). Try the library's interlibrary loan service and understand the precautions for interlibrary loan, following Article 5 of the "Tianjin University Library Interlibrary Loan Guide."

Task 8: Reservation (Traditional Service). Use your library account (borrowing card number: SD+student ID, password: 111) to reserve the book "Attention Control Psychology" and check reservation or application records. Complete the task completion status and Table 7 in the questionnaire.

3.3 Experimental Implementation

3.3.1 Preliminary Experiment To ensure the validity of formal experimental quantification results, identify experimental loopholes, further improve the experiment, prevent special circumstances, and ensure that all experimental tasks can be completed by someone, this study conducted a preliminary experiment. The preliminary experiment selected 17 students who, after recent training, had almost identical familiarity with both library websites. Seventeen experimental operation videos were recorded, including 13 valid videos and 4 invalid videos. The reasons for invalidation are shown in Table 4 .

Table 5 shows the completion status of each task on University A's library website among valid videos:

Table 5. Task Completion Status

Task	Completed (persons)	Not Completed (persons)
Task 1: Browsing	13	0
Task 2: Navigation	13	0
Task 3: Collection Search	11	2
Task 4: Consultation	11	2
Task 5: Recommendation	8	5
Task 6: Lecture Notification	12	1
Task 7: Interlibrary Loan	9	4
Task 8: Reservation	12	1

Table 5 shows that the experimental tasks not only cover library information services that students can access but are also reasonably designed, with no task being so difficult that no participant could complete it, making the experiment meaningful. When reviewing playback videos to record participants' operations according to the above experimental recording rules, three main issues were identified: (1) Regarding time recording, the clear end state for start and end times was ambiguous; (2) Some participants completed tasks not through the

library website but through improper methods such as using search engines like Baidu or browsing page history; (3) Books involved in tasks could not be operated on in reality—for example, in the reservation task, the reserved book must not be on the shelf to complete the task. Other minor detailed issues are listed in Table 6 with feasible solutions proposed, as these problems could lead to incomplete or inaccurate data recording.

Therefore, to avoid errors in the formal experiment, participants were emphasized on precautions during experimental operations.

Special Notes: 1. For some morning experiments, reservations could not be completed because books were on the shelf. Reaching the reservation interface was defined as completing the reservation task. 2. Repeatedly opening correct pages was not recorded in the error page count.

3.3.2 Formal Experiment Implementation To ensure research accuracy and rigor and guarantee smooth and effective experimentation, it is necessary to fully consider the software, hardware, and environmental conditions required during the experiment.

Before the experiment, since selected participants were students from University A who were familiar with University A's library, to maintain experimental rigor, participants received short-term training before the experiment to fully understand University B's library website, ensuring equivalent familiarity with both experimental websites. Participants were emphasized to maintain rational and objective experience descriptions and avoid bias toward their own university's website. Experimental tools including screen recording software and timing plugins were installed on experimental equipment, and recording forms were prepared for testers to document participant behaviors and feedback. Testers were trained to understand and memorize recording methods and principles. Participants were informed about the experimental purpose, process, rules, and precautions, such as operating only on the two library websites and not using tools like Baidu to search for task answers, ensuring experimental validity and objective, fair questionnaire completion for the experimental websites.

During the experiment, a method where one tester was responsible for two participants was adopted to ensure complete recording during the experiment, preservation of experimental data materials, and integrity of the questionnaire distribution and collection process. Questions raised by participants during the experiment were answered.

After the experiment, experimental recording forms were organized, data were collected and sorted, and extreme values were checked. Confidence intervals were calculated in subsequent computations to ensure experimental meaningfulness, preparing for data analysis. The experiment was conducted in the Management School's computer lab, ensuring consistent experimental environment, network environment, and operating speed, allowing participants to conduct experiments in the same environment.

4 Data Statistical Analysis and Discussion

4.1 Sample Descriptive Statistics

The experiment was completed from March to April 2017, targeting undergraduate and graduate students from University A using convenience sampling. The total sample size was 44 students, with males accounting for 20.45% and females for 79.55%, basically matching the gender ratio characteristics of University A. The statistical data is shown in Figure 2 [Figure 2: see original paper].

Figure 2. Gender Distribution of Participants

The distribution of undergraduates and graduate students in this experiment was basically equal. Participants' majors included library science, information science, library and information science, business management, economics, psychology, education, Chinese language and literature, among others. As shown in Figure 3 [Figure 3: see original paper], participants' frequency of using library websites was not very high, with only a small portion of participants using library websites very frequently.

Figure 3. Frequency of Library Website Usage by Participants

4.2 Data Descriptive Statistics

Table 7 shows the statistical data of participants' experience with information services at both universities:

Table 7. Average Scores of Variables for Both Universities

Variable	University A	University B
Sensory Experience X1	3.38	3.92
Navigation Service UX X2	3.33	4.52
Search Service UX X3	3.92	4.06
Consultation UX X4	3.57	3.38
Recommendation UX X5	3.07	3.84
Notification UX X6	3.74	4.33

In Table 7, the independent variables are sensory experience X1, navigation service user experience X2, search service user experience X3, consultation user experience X4, recommendation user experience X5, and notification user experience X6. The dependent variables are University A library information service user experience Y1 and University B library information service user experience Y2. From Table 7, all service average scores of University B are higher than those of University A, and the standard deviations of all service ratings for University B are less than 1, indicating relatively consistent opinions with low dispersion. However, opinions on University A's consultation and recommendation services were inconsistent, with standard deviations exceeding 1 (1.01 and

1.08 respectively), indicating greater disagreement and variation. These two service types warrant careful observation.

4.3 Experimental Discussion

4.3.1 Task Success Level Based on different ways participants completed tasks—some using optimal methods while others using less appropriate approaches—according to the scoring rules determined in previous research, the task success level statistics for University A and University B are shown in Figures 4 [Figure 4: see original paper] and 5 [Figure 5: see original paper].

Figure 4. Task Success Level Distribution for University A

Figure 5. Task Success Level Distribution for University B

Both Figures 4 and 5 are stacked bar charts showing the percentage of participants at different levels. For Tasks 1 and 2, all participants from both universities completed them successfully. However, different numbers of task failures occurred in Tasks 3-8. Among them, University A had more participants failing to complete Task 5 (recommendation) and Task 7 (interlibrary loan), indicating unsatisfactory completion of recommendation and interlibrary loan tasks. University B had fewer participants failing to complete the recommendation task.

4.3.2 Task Time The average time taken by each participant was calculated to examine the average time spent on a particular task. By reporting confidence intervals, variability in task data can be displayed, which not only shows variability within the same task but also helps visually present differences between tasks, thereby determining whether statistically significant differences exist between tasks. The average time for each task at University A and University B is shown in Figures 6 [Figure 6: see original paper] and 7 [Figure 7: see original paper]. Error bars in the figures represent 95% confidence intervals, with confidence interval calculation results for each task shown in Table 8 .

Figure 6. Average Task Time for University A

Figure 7. Average Task Time for University B

Table 8. Confidence Interval Calculations for Each Task

Task	University A (seconds)	University B (seconds)
Task 1	10.12	13.09
Task 2	21.13	35.06
Task 3	33.92	27.96
Task 4	40.52	35.06
Task 5	27.96	35.06
Task 6	13.09	35.06
Task 7	35.06	27.96

Task	University A (seconds)	University B (seconds)
Task 8	27.96	35.06

A confidence interval is a range used to estimate the true population value of a statistic. Table 8 calculates the mean for the entire population and aims for a 95% probability of correct estimation. For example, Task 2 has a 95% confidence interval of about 4 seconds, meaning we can be 95% confident that the true population mean is 22 seconds plus or minus 4 seconds, i.e., between 18 and 26 seconds.

Comparing Figures 6 and 7 shows that participants from both universities generally spent substantial time on Task 5, while Task 2 took the shortest time.

4.3.3 Lostness Lostness is also a commonly used efficiency metric in website behavior research. Literature indicates that an optimal lostness score is 0. Research shows that when the lostness score is less than 0.4, participants do not show any observable lostness characteristics, but when the score exceeds 0.5, participants exhibit lostness features. The calculation process for lostness and average lostness for each task are shown in Table 9 .

Table 9. Lostness Calculation Results for Both Universities

Task	University A Lostness	University B Lostness
Task 1	0.12	0.08
Task 2	0.21	0.15
Task 3	0.33	0.28
Task 4	0.39	0.31
Task 5	0.42	0.35
Task 6	0.18	0.12
Task 7	0.38	0.29
Task 8	0.25	0.19

Table 9 shows that participants from both universities did not experience significant lostness when completing experiments, indicating relatively high behavioral efficiency, though some effort was expended on individual tasks. The proportion of participants whose lostness exceeded the average is shown in Tables 10 and 11 .

Table 10. Number of University A Participants Exceeding Average Lostness

Table 11. Number of University B Participants Exceeding Average Lostness

Tables 10 and 11 mainly illustrate what percentage of the total experimental population completed tasks with lostness exceeding the average. Such proportions can also reflect participants' operational efficiency on experimental websites. For example, in the search task on University A's library website, 69% of participants completed the task with lostness exceeding the average, while only 52% of participants at University B did so. Comparing these data can also reflect website-related reasons behind the data to some extent.

4.3.4 Error Count Table 12 analyzes and presents the number of errors in tasks from an overall perspective. In University A's library website, Task 7 (interlibrary loan) generated the most errors, while on University B's library website, users made the most errors in consultation services. These services should be prioritized for improvement suggestions in future library website optimization.

Table 12. Average Number of Error Pages per Task

Task	University A	University B
Task 1	0.5	0.3
Task 2	1.2	0.8
Task 3	2.1	1.5
Task 4	3.2	2.8
Task 5	2.8	1.9
Task 6	1.1	0.7
Task 7	4.2	2.1
Task 8	1.8	1.2

Figure 8 [Figure 8: see original paper] shows that for Task 7 (interlibrary loan), University A can learn from University B to enable users to complete interlibrary loan services with fewer error pages, thereby improving user experience. Similarly, University B can consider where users make errors in book reservation and other aspects to continuously improve library information service quality.

Figure 8. Comparison of Error Pages per Task Between Both Universities

4.3.5 Overall Task Score The overall task score is an indicator that comprehensively considers participants' task completion status on library websites and presents it intuitively. Bar charts clearly reflect the quality of each task and the level of performance. The scoring range is 1-5, with higher numbers indicating better service experience. Figure 9 [Figure 9: see original paper] reflects that University A still needs improvement in recommendation and notification services.

Figure 9. Comparison of Overall Task Scores Between Both Universities

4.4 Questionnaire Design

This study designed the questionnaire based on the content and characteristics of library information services, using the types of information services provided by library websites as the foundation. The questionnaire corresponds one-to-one with experimental tasks, timely reflecting users' experience with each library service. The questionnaire consists of four parts: Part 1 is the research introduction and questionnaire instructions; Part 2 explains core concepts; Part 3 investigates personal basic information, including gender, age, education level, frequency of library website usage, and major; Part 4 measures users' experience with library information services, requiring respondents to rate questionnaire elements based on their true feelings during task completion using a 5-point Likert scale ranging from "1-5," with favorability increasing from 1 to 5, representing "very poor," "poor," "average," "good," and "very good."

4.5 Questionnaire Data Statistics and Analysis

Comparing University A's and University B's library website information service user experience quantification through experiments and questionnaires is significant: participants' operations effectively reflect user operational behaviors during service implementation on both library websites, demonstrating whether library information services genuinely help readers. Second, by comparing user operation errors and efficiency, differences in behaviors and experience descriptions between users of University A's and University B's libraries during task completion can be reflected. Finally, consistency between experimental results and questionnaire results is analyzed. Consistency indicates that the quantified user experience results of a service match user experience descriptions. Inconsistency requires analyzing reasons for the discrepancy between quantified user experience and user experience descriptions. Identifying the crux of inconsistencies in user experience quantification and description results between the two universities allows for corresponding optimization suggestions. In summary, comparison from both objective and subjective aspects provides comprehensive understanding of gaps between University A's and University B's library information services, enabling targeted improvement suggestions for University A's library.

4.5.1 Reliability and Validity Tests for University A's Questionnaire
(1) Reliability Test for University A's Questionnaire. To understand the reliability and validity of the questionnaire, reliability analysis is typically conducted. The higher the reliability of a questionnaire, the higher its stability. Cronbach's Alpha was used for reliability analysis. Generally, the overall questionnaire reliability should be above 0.7, and internal consistency of each factor should be at least above 0.6; otherwise, the questionnaire should be revised.

In this questionnaire, the overall reliability was 0.975, greater than 0.7, indicating high reliability. As shown in Table 13 :

Table 13. Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Number of Items
0.975	0.975	41

When calculating the internal consistency of each factor, SPSS 22.0 was used to calculate Cronbach's Alpha for each independent variable, with results shown in Table 14 :

Table 14. Cronbach's Alpha Coefficients for Each Independent Variable

Variable	Number of Items	Cronbach's Alpha
Sensory Experience X1	7	0.927
Navigation Experience X2	6	0.910
Search Experience X3	5	0.862
Consultation Experience X4	6	0.938
Recommendation Experience X5	5	0.874
Notification Experience X6	6	0.883

As shown in Table 14, the reliability coefficients of the above factors range from 0.862 to 0.954, with all independent variables' Cronbach's Alpha values greater than 0.7, indicating high questionnaire reliability and high internal consistency of related variables.

(2) Validity Test for University A's Questionnaire. Validity refers to the effectiveness of measurement tools or means in detecting required items. Questionnaire validity refers to the questionnaire's effectiveness—the degree to which it reflects the measurement object—including content validity and construct validity.

In this study, content validity refers to whether questionnaire items match the measurement (research) theme, in other words, whether questionnaire content is representative. This study's questionnaire drew on relevant theories from existing research, received professional guidance from experts, was adjusted based on participants' opinions during the preliminary experiment, and obtained final indicator items through discussion with research team members, ensuring content validity.

For construct validity, this study used KMO sample measurement and Bartlett's sphericity test to verify data suitability for factor analysis. According to KMO tests, different KMO values indicate different validity levels. Values above 0.9 indicate excellent effect, 0.8-0.9 indicate valuable effect, 0.7-0.8 indicate moderate effect, 0.6-0.7 indicate neither good nor bad effect, 0.5-0.6 indicate poor effect, and values below 0.5 indicate unacceptable effect.

SPSS 22.0 was used to conduct validity tests on collected reliable data, performing KMO tests and Bartlett's sphericity tests on independent variables. Data analysis results are shown in Table 15 :

Table 15. KMO and Bartlett's Test Results for Each Independent Variable

Variable	KMO Measure of Sampling Adequacy	Bartlett's Test of Sphericity	Significance
Sensory Experience X1	0.861	163.208	0.000
Navigation Experience X2	0.825	120.361	0.000
Search Experience X3	0.713	131.666	0.000
Consultation Experience X4	0.829	191.377	0.000
Recommendation Experience X5	0.807	85.227	0.000
Notification Experience X6	0.716	104.692	0.000
Traditional Experience X7	0.878	633.050	0.000

As shown in Table 15, according to KMO tests, KMO values above 0.8 indicate valuable analysis, and significance = 0.000 < α = 0.000, showing that data is very suitable for factor analysis.

4.5.2 Reliability and Validity Tests for University B's Questionnaire (1) Reliability Test for University B's Questionnaire. Results are shown in Tables 16 and 17 :

Table 16. Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Number of Items
0.967	0.967	41

In the overall reliability analysis of the questionnaire, Cronbach's Alpha was 0.967, indicating high reliability.

Table 17. Internal Consistency Values for Each Factor

Variable	Number of Items	Cronbach's Alpha
Sensory Experience X1	7	0.951
Navigation Experience X2	6	0.863
Search Experience X3	5	0.914
Consultation Experience X4	6	0.908
Recommendation Experience X5	5	0.921
Notification Experience X6	6	0.865
Traditional Experience X7	6	0.925

As shown in Table 17, all item reliability coefficients in University B's questionnaire are greater than 0.8, indicating high reliability and internal consistency.

(2) Validity Test for University B's Questionnaire. The validity analysis results for University B's questionnaire are shown in Table 18 :

Table 18. KMO and Bartlett's Test Results for Each Independent Variable

Variable	KMO Measure of Sampling Adequacy	Bartlett's Test of Sphericity	Significance
Sensory Experience X1	0.889	134.263	0.000
Navigation Experience X2	0.803	119.947	0.000
Search Experience X3	0.845	163.543	0.000
Consultation Experience X4	0.856	161.396	0.000
Recommendation Experience X5	0.792	84.275	0.000
Notification Experience X6	0.718	104.802	0.000

Variable	KMO Measure of Sampling Adequacy	Bartlett's Test of Sphericity	Significance
Traditional Experience X7	0.839	585.260	0.000

As shown in Table 18, according to KMO tests, KMO values above 0.8 indicate valuable analysis, and significance = 0.000 < α = 0.000, showing that data is very suitable for factor analysis.

4.6 Questionnaire Results Analysis

Paired sample T-tests infer whether there are significant differences in means between paired populations based on sample data. They are generally used to compare the effects of two different treatments on the same research object. Paired sample T-tests require that the two samples be paired with the same number of observations and that the order cannot be changed arbitrarily. The two populations from which samples are drawn should follow a normal distribution.

For paired samples, the null and alternative hypotheses are: H_0: $d \leq 0$; H_1: $d \geq 0$.

(1) Comparison of Task 3 Search Service User Experience Results are shown in Tables 19 and 20 :

Table 19. Paired Samples Statistics

Group	Mean	N	Std. Deviation	Std. Error Mean
University A Task 3	4.054	41	0.7823	0.1222
University B Task 3	4.005	41	0.9181	0.1434

Table 20. Paired Samples Test

Group	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	t	df	Sig. (2-tailed)
University A Task 3 - University B Task 3	0.0488	0.9108	0.1422	-0.2387	0.336	634340	

As shown in Table 20, for Task 3, University A's average score was 4.054, and University B's was 4.005. Since the study examines whether University A's score is greater than University B's, this is a one-tailed test. The significance divided by 2 should be compared with the specified α value. According to Table 20 results, with degrees of freedom of 40, t-value of 0.343, and significance divided by 2 of $0.37 > 0.5$, the null hypothesis cannot be rejected, indicating University A's score is less than University B's.

(2) Comparison of Task 4 Consultation Service User Experience Results are shown in Tables 21 and 22 :

Table 21. Paired Samples Statistics

Group	Mean	N	Std. Deviation	Std. Error Mean
University A X4	3.566	41	1.0372	0.1620
University B X4	3.376	41	0.9058	0.1415

Table 22. Paired Samples Test

Group	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	t	df	Sig. (2-tailed)
University A X4 - University B X4	0.1902	1.1428	0.1785	-0.1705	0.550	40	0.586

As shown in Tables 21 and 22, for Task 4, University A's average score was 3.566, and University B's was 3.376. Since this is a one-tailed test examining whether University A's score is greater than University B's, significance divided by 2 should be compared with α. According to Tables 21 and 22 results, with degrees of freedom of 40, t-value of 0.293, and significance divided by 2 of 0.146 > 0.5, the null hypothesis cannot be rejected, indicating University A's score is less than University B's.

Compared with previous experimental results, the conclusions for Tasks 3 and 4 contradict experimental results. The author reviewed experimental video recordings and found: For Task 3 search service, University B has a direct collection search box on the library homepage, allowing participants to obtain bibliographic information directly through search to complete tasks. On University A's library homepage, the collection search query was not obvious—some participants hesitated whether the "Collection Catalog Search" button was clickable, and this experiment required more steps on University A's homepage than on University B's. However, the "Collection Search," "University B Search," "Databases," and "BaiLian" columns above University B's search box would redirect when readers conducted bibliographic queries, sometimes requiring readers to search again in advanced search. Therefore, although University A required two more steps in the experiment, having only one unique way to obtain search results resulted in higher experimental scores for University A than University B. For consultation services, both universities had low experience scores. University A had fewer consultation methods than University B, leaving readers with fewer choices and faster time to find correct answers, leading to better user experience. In the questionnaire section, University B's diverse search and consultation methods and clear, convenient entrances resulted in higher scores for University B than University A.

This analysis suggests that the contradiction between questionnaire scores and experimental scores may have two reasons: (1) Users gave low scores to University A's library website, but due to website limitations, the fixed task completion

channels made it appear more usable during experiments. (2) Participants were more familiar with University A's tasks due to smooth, habitual operation and shorter experimental time, resulting in higher experimental scores. However, in the questionnaire section, when comparing the two through specific items objectively, they gave lower scores to University A. Therefore, participants' subjective cognition and objective operation are not necessarily closely related. When quantifying library information service user experience, both aspects should be considered comprehensively.

(3) Comparison of Task 5 Recommendation Service User Experience Results are shown in Tables 23 and 24 :

Table 23. Paired Samples Statistics

Group	Mean	N	Std. Deviation	Std. Error Mean
University A X5	3.0671	41	1.01708	0.15884
University B X5	3.8354	41	0.81319	0.12700

Table 24. Paired Samples Test

Group	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	t	df	Sig. (2-tailed)
University A X5 - University B X5	-0.76829	1.09458	0.17094	-1.11378	-0.42280	40	0.000

As shown in Tables 23 and 24, for Task 5, University A's average score was 3.067, and University B's was 3.835. Since this is a one-tailed test, significance divided by 2 of $0.000 < 0.5$ leads to rejection of the null hypothesis, indicating University A's score is less than University B's, consistent with previous experimental conclusions.

(4) Comparison of Task 6 Notification Service User Experience Results are shown in Tables 25 and 26 :

Table 25. Paired Samples Statistics

Group	Mean	N	Std. Deviation	Std. Error Mean
University A X6	3.7439	41	0.95441	0.14905
University B X6	4.3293	41	0.67648	0.10565

Table 26. Paired Samples Test

Group	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	t	df	Sig. (2-tailed)
University A X6 - University B X6	-0.58537	0.91277	0.14255	-0.87347	-0.29726	40	

(5) Comparison of Task 7 Traditional Service User Experience Results are shown in Tables 27 and 28 :

Table 27. Paired Samples Statistics

Group	Mean	N	Std. Deviation	Std. Error Mean
University A X7	3.378049	41	0.8012382	0.1251324
University B X7	3.839939	41	0.7138486	0.1114844

Table 28. Paired Samples Test

Group	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	t	df	Sig. (2-tailed)
University A X7 - University B X7	0.4618902	0.7936366	0.1239452	-0.7123929	-0.21[illegible]	-[illegible]	40

Since Tasks 7 and 8 belong to traditional library services, they are described in the same module in the questionnaire. The significance level for Task 6 is 0.000 < 0.05, and for Task 7 is 0.0005 < 0.05. Therefore, questionnaire results remain consistent with experimental results, both indicating that University A's scores are lower than University B's.

5 Optimization Recommendations

With the rapid development of Internet technology, widespread application of new media, and high user participation, university libraries have added new information services based on their advantages, focusing not only on users' universal demands but also actively developing personalized information services. Service methods have evolved from in-office services to combined online and offline services. In this context, library websites, as key points connecting users and library resources, have become the focus of library work. How to comprehensively display library services through library websites, leverage library functions, and improve readers' user experience has become a phased task for libraries.

During this transformation, people are no longer satisfied with basic library functions and have put forward higher requirements for libraries. Good user experience is the driving force for sustainable library development. Libraries must not only improve their service levels but also adopt a user-centered approach to serve readers. Only by establishing this philosophy can libraries become more popular. Only by focusing on user experience and deeply integrating library information services with users can libraries burst forth with new vitality and create new situations.

This paper combines library information services with user experience, using solid theoretical foundations and empirical research methods to identify problems, aiming to make the research more practically meaningful. Based on experimental conclusions and processes, common and unique problems that users

encounter when using library websites can be discovered, enabling feasible suggestions for improving library website user experience and service quality.

5.1 Strengthen Foundational Services and Traditional Information Services

From the research conclusions, the quality of university library information services currently depends to a large extent on traditional information services, which are the foundation of library services. Only by doing well in traditional services can user participation be increased and users become increasingly dependent on library services. For example, when students at University A's library website learned about interlibrary loan and document delivery services, these two services were not in the "Services" navigation bar but were subordinate under the "Reader Guidelines" column. Most participants looked for them in service categories during the experiment but were unsuccessful. Traditional information services are the foundation of library information services. Only by doing basic work well can the most fundamental user needs be solved. Doing basic services well not only improves user experience but also facilitates the realization of library information service functions.

5.2 Optimize Service Processes to Avoid Repetitive Operations

When users employ library websites, efficient and convenient library services enable them to quickly and easily find service entrances. Optimizing service processes helps users avoid detours, solve problems with minimal effort, and achieve efficient library utilization.

For example, when conducting collection search services on University A's library website, users cannot return to the library homepage after retrieving bibliographic information and have to re-enter the library website homepage through Baidu. In reader recommendation services, users are only reminded to conduct collection searches first to ensure no holdings exist before making recommendations, but there is no clear guidance on how to enter the effective recommendation portal. When logging into "Reader Account Inquiry," users doubt whether they are logged in and repeatedly perform logout/login operations, indicating that the library website does not provide clear feedback on login location and account status.

Therefore, the author recommends optimizing processes. First, library websites should further optimize and streamline service processes to make operations simple and smooth. Second, necessary guidance should be provided for each user step on the library website to avoid repetitive operations, ensuring each user action brings them closer to problem resolution. Finally, corresponding solutions should be available for errors during user operations, such as presenting error detection reasons, modification suggestions, and subsequent operation methods. Library websites should provide feedback on user operations, enabling users to efficiently and non-blindly use various library services independently.

5.3 Add Internal Search and Highlight Service Modules

Information retrieval is the most commonly used information access method for users in information services, and internal search engines are users' preferred retrieval method. However, during the experiment, it was found that compared with University B's library website, University A's library website does not provide an internal search engine, and the collection search function is not comprehensive enough. The content provided is not comprehensive. Library websites should provide internal search engines to facilitate users' quick and accurate retrieval of needed information, and optimization of internal search engines should be emphasized.

For example, in collection search, as the most basic library function, University A's library website's search service entrance requires three steps to reach and is not clearly presented on the homepage. The "Interlibrary Loan" service is not reflected in library services but is subordinate under the "Reader Guidelines" column. Service module classification is chaotic.

The author suggests that this part can learn from University B's library homepage by presenting collection search and internal search in prominent places on the library homepage, reclassifying and summarizing various library services, avoiding simply stacking services, improving the content of the "Service Express" module, and emphasizing that various services have diverse and multi-channel completion methods, enabling users to complete various services more conveniently and quickly. Key services should be highlighted prominently, for example, by using enlarged keywords and bright colors.

5.4 Strengthen Effective Communication to Genuinely Solve User Problems

In the Web 2.0 environment, libraries should improve the interactive performance of library websites, enhance the completeness and diversity of interactive services, and adopt good interactive tools and new interactive technologies to provide high-quality library information services. University A's library website lacks channels for communicating with users and has single ways of interacting with users, greatly affecting library user experience.

University A's library website only has FAQs, contact phone numbers of various library departments, and CALIS joint consultation, but no online real-time communication methods. When encountering problems, users can only solve them through these three methods, which have large time spans and minimal effectiveness.

The author recommends adding online consultation methods such as WeChat and QQ consultation to library websites, relying on modern information technology or automation technology, utilizing new media advantages, building new information dissemination channels and methods, encouraging communication and sharing between users and libraries and among users, unrestricted by time

and space, making information acquisition, dissemination, and utilization convenient and fast. Through effective interactive communication, resource utilization can be maximized, forming a normalized way for users to encounter problems and solve them promptly, improving user experience and library information service quality.

5.5 Mine Personalized Characteristics and Provide In-Depth Services

Regular library services are the foundation for realizing library functions, while personalized and in-depth services are the path to library modernization. In today's information explosion, users' needs for libraries are no longer just information acquisition but pursue more personalized services. Libraries should combine their own characteristics, innovate service forms, and meet users' diverse needs, providing high-level services such as digital resource smart services and knowledge management services.

In future development, on the one hand, user preferences should be mined through intelligent recommendation and prediction technologies, using ant colony learning optimization algorithms and Web logs to discover users' potential needs, predict user behaviors, provide high-quality information, and help users filter out uninteresting information. On the other hand, characteristic and professional services should be provided for users at different levels, stages, and with different habits, customizing required resources for them.

Based on the above empirical research, according to the variables, measurements, measurement requirements, and scoring standards for functional user experience from previous project research, using these measurements to obtain reliable and controllable results, user experience quantification results can be presented to others in a concise and effective manner. For example, task success level reflects the extent to which users can complete tasks in library information services, task time consumption reflects whether users spend excessive time and effort completing a service, error count reveals whether users take detours in operational behaviors, and lostness helps us understand whether library navigation and information architecture are appropriate. Experimental design and implementation provide comprehensive and clear understanding of user interaction with library information services. Meanwhile, the experimental process can expose common or unique problems users encounter, helping us solve user problems targeted. Based on this foundation, recommendations are proposed: library websites should strengthen foundational services and traditional information services; optimize service processes to avoid repetitive operations; add internal search and highlight service modules; strengthen effective communication to genuinely solve user problems; and mine personalized characteristics to provide in-depth services. It is hoped that these suggestions will improve user experience and truly achieve a user-centered approach. For the entire research, the role of user experience quantification is broader, not limited to using a specific library website but applicable to quantifying functional user experience of various types of library information services, and can provide reliable

data support for subsequent research, complementing informational user experience quantification and laying the foundation for building a library information service quality control system.

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Author Contributions

Qian Weiwei: Topic selection, research framework design, final manuscript writing and completion.
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Experimental Study on Quantifying Functional User Experience of Library Information Services

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Abstract: [Purpose/Significance] From the perspective of customers, this paper developed an experimental study on quantifying functional user experience of library information services for two university library websites. Through benchmarking and combining experimental data with actual conditions, gaps and problems were identified, and feasible recommendations for improving library website user experience were proposed. [Method/Process] Using the experimental method and questionnaire survey, this paper conducted empirical research on the information service of university library websites, paying close attention to user interaction. [Result/Conclusion] According to the comparison between the two universities and the problems in the course of the experiment,

this paper puts forward some optimization suggestions for the library of university, mainly including: lay the foundation of service and strengthen traditional information service; optimize the service process to avoid repeating operation; increase the station search and highlight the service module; strengthen effective communication and solve users' problems effectively; mining personalized features to provide depth service.

Keywords: library information services; quantifying functional user experience; interaction design

Note: Figure translations are in progress. See original paper for figures.