Empirical Postprint on the Construction of User Personas for University Mobile Libraries

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Abstract

[Purpose/Significance] By employing user persona construction methods to investigate and present the differentiated behavioral characteristics of university mobile library user groups, libraries can more accurately comprehend potential user needs and actual usage behaviors, which carries significant reference value for refining library service marketing strategies. [Method/Process] This study synthesizes the current state of user persona practices in libraries, proposes a user persona tag system constructed specifically for the mobile library context, and restructures the tag description framework by adapting the VALS 2 attitudinal scale for user segmentation from the perspective of usage psychological preferences. A questionnaire based on this tag system was designed to collect data on university mobile library users' demographic attributes, usage behaviors, and usage psychological preferences. Factor analysis, cluster analysis, and discriminant analysis were utilized to determine the optimal number of user personas. The R wordcloud2 package was employed to visualize feature tag clouds for distinct user personas, with each persona described and discussed in terms of its demographic attributes, usage behaviors, and characteristic tags. [Results/Conclusion] The study presents an analytical approach for constructing user personas within specific business contexts, offering empirical research references for university mobile libraries to enhance precise user targeting and implement differentiated services.

Full Text

Preamble

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An Empirical Study on User Persona Construction for University Mobile Libraries

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Abstract

[**Purpose/Significance**] Utilizing user persona construction methods to explore and present the differentiated behavioral characteristics of university mobile library user groups helps libraries more precisely understand potential user needs and actual usage behaviors, providing important reference value for improving library service marketing strategies. [**Method/Process**] This study summarizes the practical status of user personas in libraries, proposes a user persona label system construction framework based on the specific context of mobile libraries, and reconstructs the label description system by drawing on the VALS2 user segmentation attitude scale from the perspective of usage psychological preferences. A questionnaire was designed based on the label system to survey variables including demographic attributes, usage behaviors, and psychological preferences of university mobile library users. Factor analysis, cluster analysis, and discriminant analysis were employed to determine the appropriate number of user personas. The R language wordcloud2 package was used to visually display characteristic tag clouds for different user personas, with descriptions and discussions developed for each persona based on demographic attributes, usage behaviors, and characteristic labels. [**Result/Conclusion**] The study proposes an analytical method for constructing user personas in specific business contexts, providing empirical research reference for university mobile libraries to improve precise user positioning and develop differentiated services.

Keywords: mobile library; user persona; persona construction; precision marketing

Classification Number: G250

With the rapid proliferation of smartphones and the deepening development of mobile information services, university mobile libraries have entered a stage of deepening personalized services. Currently, user needs are becoming increasingly diversified and personalized. The concept of guiding mobile library services and marketing promotion with homogenized needs often results in carefully designed user experiences and resource services that fail to match users' differentiated potential needs, leading to practical dilemmas such as user fatigue, declining usage rates, and APP user attrition. Therefore, using user behavioral characteristics to guide precision marketing in mobile libraries has become a current research hotspot. Precision marketing services must be based on a comprehensive understanding and recognition of target user behavioral characteristics to better provide personalized and diversified information services for user groups. User persona, also known as user role, currently lacks a unified definition. Interaction design pioneer A. Cooper [1] believes that user personas are virtual role descriptions built upon real user data. Through literature review and synthesis of several typical definitions [2-4], this study defines user personas as: in specific product usage contexts, using sampling surveys or big

data technology to extract multi-dimensional data including demographic attributes, behavioral habits, consumption psychology, and social characteristics, and employing data mining models to construct label content related to user personas, thereby accurately describing differentiated group characteristics. It clearly presents the complete picture of users' potential needs, usage behavior preferences, and personalized differences, providing managers with a new service innovation method for accurately identifying target users and achieving precision marketing. Therefore, this paper attempts to start from static and dynamic user behavior data, drawing on the VALS2 market segmentation method from the marketing field to construct a user persona label system for university mobile libraries. Through factor dimensionality reduction analysis, K-Means clustering, and visualization methods, it draws differentiated group user personas for mobile libraries, aiming to summarize current user behavioral characteristics and corresponding precision marketing strategies for mobile libraries, thereby improving the precision service level of mobile libraries.

2 Theoretical Foundations

2.1 Related Research on User Personas

User personas are closely related to market segmentation and require multi-dimensional customer classification, continuously intersecting and overlaying to generate rich attribute tags that present various behavioral characteristics of users. The core lies in "tagging," and tags mainly originate from information extraction, which can be drawn from multiple dimensional data sources: demographic attributes, social behavior attributes, user preference attributes, and other attributes [4]. Tags can be obtained through ETL database tools or web crawler technology to acquire user basic data from business systems, or through various survey forms such as interviews, questionnaires, and in-depth investigations [5]. Common persona modeling methods include statistical analysis [6], vector space models [7], topic model extraction [8], and neural network-based user modeling [9]. Currently, there are many studies on user persona construction using big data technology and data mining models, which essentially involve modeling multi-dimensional tag combinations [10], a process of extracting user persona tags based on users' demographic attributes and usage behavior characteristics.

2.2 Related Research on VALS2 Market Segmentation

Among user segmentation methods in the marketing field, the VALS2 (Values and Lifestyles) model, based on Maslow's hierarchy of needs and motivation theory, posits that individuals' lifestyles and values influence their behavior patterns. It combines demographic characteristics, lifestyles, beliefs, values, attitudes, and beliefs to compile the VALS scale [11]. This scale is built upon stable user psychological characteristics and can comprehensively reflect the behavioral patterns that influence users' product or service usage. The scale includes 4 demographic variables and 35 attitude scale statements. Its creator,

A. Mitchell, established a consumer segmentation model based on consumption values through empirical research. In 1989, the VALS model incorporated psychological measurement factors and evolved into VALS2. Based on theoretical models of fundamental human social values, VALS2 demonstrates strong applicability and higher measurement validity, with stable segmentation results that are highly beneficial for user persona construction and grouping.

VALS2 has been widely introduced and applied in countries including the UK, Japan, and China, with its validity gaining international recognition. It has gradually constructed market segmentation models suitable for different cultural backgrounds [12]. The most representative in China is the China-VALS scale developed by Wu Yin [13], which uses respondents' lifestyles as classification variables to establish a 5-level, 14-group value classification structure. Currently, VALS2 has been widely applied in retail, banking and securities, news media, and insurance industries. As an ex-post segmentation method, it integrates variables such as values, lifestyles, and resources, using self-orientation and resources as distinguishing dimensions to comprehensively reflect users' values and attitude indicators regarding product usage, thereby promoting resource allocation optimization and improving economic benefits.

2.3 Research Status Analysis and Significance

As a tool for achieving precision marketing and meeting customers' personalized needs, user persona applications in university libraries at home and abroad have been increasing in recent years. Foreign applications of user personas have focused more on improving library website user experience research to present specific user social network images. For example, Z. Holt [14] used university libraries as a case study to elaborate on the construction of user personas and their evolving development process. R. M. Marrall, K. Nora, and D. J. Burmeister [15] established a usability and design working group specifically to meet the usage needs of Western Washington University library users, employing user persona technology to identify various user types on the website, thereby enhancing the precision and convenience of website services for teaching and research. With the deepening application of user persona technology, recent research has emerged on using precise descriptions of diversified user needs to improve library precision marketing products and services. For instance, Z. Holt and S. Rackham [16] used user personas and principal component analysis to identify 10 different library user roles and needs at Brigham Young University, improving and creating business services that match users' diverse needs from a strategic planning perspective. M. Otterlo [17] used library business services as an example, proposing to collect usage behavior interaction information from various service interaction points between users and libraries, draw user personas using market segmentation methods, and provide them to librarians through visual displays to optimize corresponding library services. M. K. A. Shboul and A. Abrizah [18] applied user personas to precisely describe humanities scholars' information search behaviors, thereby providing information

sources and library services for diversified library user needs. C. Lewis and J. Contriño [19] introduced how librarians used user personas to describe distance education users' cognition and barriers in utilizing digital libraries and research, thereby designing digital resources and portals that match library users.

Domestic scholars have conducted related research combining user personas with user needs from the perspective of precision marketing of library services. Li Yegen [20] proposed randomly sampling user samples, extracting key data related to information needs such as users' demographic characteristics and behavioral variables, and using data mining tools to accurately grasp user information demand characteristics to carry out precision marketing services for libraries. Wang Dengxiu, Zhang Wende, and Lin Xiyang [21] designed personas for university digital library alliances based on the VALS2 lifestyle scale, thereby precisely positioning different user groups and providing personalized marketing service strategies. Qiu Huilin [22] pointed out that user personas will become an important technical means for libraries in developing precision services. Zhu Bai [23] proposed analyzing reader user data and modeling, tagging users with basic and behavioral information, and drawing reader "facial profiles" to achieve precise positioning of reader preferences. Liu Su [24] used Tianjin Library as an example to construct user personas in digital library knowledge discovery systems from aspects of data sources, data collection, information identification, and model building. Wang Xiaowen et al. [25] introduced the VALS2 market segmentation method and provided precision marketing strategies for discipline services targeting different sub-markets from three aspects: discipline service product design, service promotion, and differentiated services.

In summary, user personas fully align with libraries' business needs and practical exploration for developing refined marketing in user service fields. However, few scholars have conducted empirical research on describing mobile library user behavior characteristics from the perspective of user psychological preferences, and there is no literature providing systematic discussion on user persona construction, cluster analysis, label drawing, and precision service strategies in business contexts. Therefore, this paper attempts to use university mobile libraries as an empirical research object, drawing on VALS2 lifestyle paradigm consumption psychological behavior indicators and users' demographic characteristics to construct user persona labels, multi-dimensionally revealing various user personas in the current development stage of mobile libraries, deeply analyzing their usage psychology and tendencies, finely positioning the group characteristics of main audiences, and providing visual decision support for mobile libraries in service marketing improvement. This will enhance the precision of university libraries in resource and service marketing, user retention, and innovative services.

3 Research Design

Virtual user personas built upon numerous real data represent differentiated label descriptions of users after segmentation. Therefore, selecting appropriate segmentation methods becomes key to user persona modeling. The label con-

tent and corresponding weights of personas determine the degree of difference among each segmented group, explicitly displaying the unique service needs of each group, which in turn influences the implementation of different marketing strategies. The following sections elaborate on the research design, including user persona label framework construction, label weight design, and empirical modeling of user personas.

3.1 User Persona Label Framework Construction

Based on the usage context of mobile library users and following the principle of "designing on demand without infinite refinement," this study establishes the two basic factors of "consumer resources" and "self-orientation" from the VALS2 scale as segmentation indicators to construct the label framework for user personas.

3.1.1 Consumer Resources In the VALS2 scale, consumer resources refer to users' income, education, confidence, health, purchase desire, intelligence, and ability level. The mobile library user persona labels cover four demographic variables: gender, grade, discipline, and identity type, while also including three variables: access method, access frequency, and access device, corresponding to usage willingness and ability level.

3.1.2 Self-Orientation In the VALS2 scale, self-orientation refers to three verified motivational orientations: principle-oriented, status-oriented, and action-oriented. Based on the usage context of mobile library users and product business objectives, the user persona label design is as follows: principle-oriented mainly involves users' subjective cognition, such as collection inquiry, resource acquisition, information subscription, and interface guidance in the mobile library APP; status-oriented mainly covers social sharing, peer recognition, librarian service support, and training lectures within the APP functions; action-oriented mainly includes users' social and material behaviors, activities, and changes, such as participation in reward activities in the mobile library APP, proficiency in function operation, accessibility of various devices, and degree of fragmented usage.

The final user persona label system is shown in Figure 1 [Figure 1: see original paper], consisting of three parts: first, demographic attributes, containing 4 statistical variables; second, usage behavior attributes, containing 3 survey variables; and third, user psychological preference labels, which are correspondingly divided into 22 psychological survey variables in the VALS2 scale as principle-oriented, status-oriented, and action-oriented.

3.2 User Persona Label Weight Design

The difference in user personas lies in label weights, which are determined by business requirements. Starting from the closeness of user contact with products or services, label weights are mainly influenced by decay factors, behavior weights, and contact point weights [26]. A typical method is to calculate user

label weights by summarizing 4W (who/when/where/what) factors, covering user type priority, time length and span, login duration, access frequency, and number of contact points [27]. However, these weight data also depend on SDK embedding in websites and activity pages to transmit data to backend databases in real-time. Since mobile libraries have not yet designed mechanisms for real-time collection of user behavior data in APPs, and the psychological behavior preference labels constructed with VALS2 indicator system represent stable service perception attitude values in the short term, expressed as Likert scale values from low to high indicating users' value recognition degree after multiple uses of products or services. Therefore, this study uses the statistical mean of each psychological preference variable in each group as the label weight, while the demographic and usage behavior dimensions use frequency ranking of attribute values to jointly define the three types of label weights for user personas.

3.3 Empirical Approach and Process Design

After establishing the label connotations, construction dimensions, and weight values required for user personas, the empirical modeling design is shown in Figure 2 [Figure 2: see original paper]. First, regarding data source acquisition for user persona labels, according to related discussions on user persona label construction [28], obtaining user behavior label values through data extraction and analysis tends to be costly and raises privacy concerns. Additionally, current university mobile library APPs have not implemented page-level code tracking and recording of user behavior data. Therefore, the author adopts questionnaire surveys for data collection. The determination of the number of user personas involves using factor dimensionality reduction to extract key characteristic factors, employing cluster analysis to obtain the number of differentiated user groups, and using discriminant analysis to select an appropriate grouping scheme. To visually display and explore corresponding precision marketing service strategies, this study uses the R language wordcloud2 package to draw psychological behavior tag clouds for each user persona.

4 Empirical Analysis

4.1 Basic Data Acquisition and Quality Analysis

Based on the three-dimensional indicators constructed above, and because user personas are closely tied to specific contexts when drawing labels, this study conducted in-depth interviews with mobile library users through focus groups to improve the variable indicator statement descriptions of user personas from the perspective of attitude scales. The questionnaire included 29 statements covering the previously constructed three major dimensions: user demographic attributes, usage behaviors, and psychological preference descriptions. Random samples of library staff, faculty, and student readers from the author's university library (hereinafter referred to as "our library") were selected for pilot testing, and some statement descriptions were semantically revised based on feedback.

The formal online questionnaire was released through the library website, official Weibo, and WeChat public account during the library promotion month activity period. Survey participants were limited to our library readers who had already used the mobile library. After 30 days of distribution, 1,500 questionnaires were collected, with 1,450 valid questionnaires. The sample size complied with MacLeff's [29] recommendations regarding the ratio of sample size to indicator variables.

Before label modeling, questionnaire data fields were cleaned in terms of format and content to remove logical errors and missing values, deleting 20 duplicate cases. After outlier processing, 1,260 valid cases were obtained. Quality verification in SPSS revealed that the male-to-female ratio was approximately 1:2. Cross-tabulation analysis of gender and discipline categories showed this ratio was consistent with the gender distribution of readers in normal universities [30], requiring no questionnaire weighting. Sample structural characteristics are shown in Table 1 .

Excluding demographic characteristic variables, other VO scale statements were included in reliability and validity analysis. As shown in Table 2 , the Cronbach's Alpha coefficient was 0.941 (>0.7), indicating high questionnaire reliability. Alpha coefficient analysis showed that the "Cronbach's Alpha if item deleted" values for the 22 statements ranged between 0.937-0.942. The high degree of consistency in repeated measurements indicated that no questionnaire items needed deletion. As shown in Table 3 , the KMO value was 0.967 (>0.7) with significance level P<0.001, indicating the data was highly suitable for factor analysis.

4.2 Factor Dimensionality Reduction and Classification Label Extraction

To obtain the number of differentiated user personas, SPSS software was used to reduce the dimensionality of 22 variables in the user psychological preference dimension and extract their characteristic factors. In SPSS, user psychological preference scale statements were entered into the "dimension reduction" module for "factor analysis," with "maximum variance rotation" set for factor extraction. The initial extraction principle was set as eigenvalues greater than 1. Considering the principle that common factors should not be too numerous, and combining factors such as the scree plot (Figure 3 [Figure 3: see original paper]), rotated component matrix, and total variance explained, this study determined that selecting 5 common factor components was appropriate. The "rotation sums of squared loadings" cumulative variance explanation reached 63.8%, as shown in Table 4 .

Based on the factor loadings of each factor on the original variables in Table 5 , the classification characteristic factors of user personas are summarized as follows:

Characteristic Factor 1: This factor is related to operation training, video

courses, information subscription, electronic newspapers, library announcements, librarian services, and social sharing. These factors collectively reflect users' cross-media reading habits on mobile intelligent terminals. This common factor can be named the omnimedia reading factor.

Characteristic Factor 2: This factor is related to e-books, journal articles, collection inquiry, and dissertations, mainly manifesting as users' demand for library digital resources, and the common factor is named the resource demand factor.

Characteristic Factor 3: This factor is related to interface identification, resource updates, cloud storage, and access convenience. These four indicators collectively reflect users' experience requirements for terminal devices (primarily smartphones) in daily use. It can be named the user experience factor.

Characteristic Factor 4: This factor is related to herd mentality, promotional prizes, and fragmented usage. It reflects the usage psychological characteristics of initial mobile library users. This common factor is named the conformity participation factor.

Characteristic Factor 5: This factor is related to APP function proficiency, network access speed, and device performance. These three indicators demonstrate the core technical elements of readers' APP usage on smartphones and can be comprehensively named the operational technology factor.

In the rotated component matrix, according to scholar Zhang Wentong's [31] suggestion on factor selection, factor coefficients below 0.45 can be ignored. The "bookshelf function" factor was deleted, reflecting that with the improvement of mobile internet speed and reduction of mobile data costs, our library readers' dependence on the offline bookshelf function of mobile libraries has gradually decreased, with online reading increasingly becoming the reading habit of mobile library users.

4.3 User Persona Cluster Analysis

After extracting the five differentiated characteristic factors for user personas, this study selected the K-means algorithm to cluster all samples and establish the number of user personas. K-means cluster analysis is an exploratory empirical research method that requires pre-specifying the number of clusters. According to suggestions from relevant scholars [32-33] on the empirical application of clustering algorithms in user segmentation, the number of clusters can be limited to a range of 4-7 categories. For optimal cluster scheme selection, discriminant analysis combined with the Wilks' lambda selection rule [21] was used to select the final clustering scheme, considering the specific context of mobile library user lifecycle stages.

In K-Means rapid clustering, the number of clusters was specified as 4-7. When the number of clusters was 7, two small categories appeared, so this scheme was abandoned. When the number of clusters was 4, 5, and 6, the Sig values of

the five common factors were all significant. When the number of clusters was 6, the F-values of each common factor in the ANOVA table showed basically no difference, indicating that the differences between user personas were not obvious, so this scheme was discarded. Comparing the schemes with 4 and 5 clusters, the discriminant analysis correct classification probability was higher for the 4-cluster scheme. From the perspective of Wilks' lambda value changes, when the number of clusters decreased from 5 to 4, this value increased significantly, indicating better F-value differences (see Table 6). Therefore, this study selected 4 as the number of user personas.

When user personas were clustered into 4 categories, the final cluster center means extracted from SPSS (as shown in Table 7) indicated that each user persona had obvious differences across various characteristic factors.

4.4 User Persona Visualization

To intuitively display the user personas obtained from the above cluster analysis, this study used the R language wordcloud2 package to draw psychological behavior preference tag clouds. Based on the above discussion, the font size of each characteristic variable tag is determined by the corresponding mean value of this user persona. A larger font size indicates more prominent characteristics, while demographic attributes and usage frequency attributes are presented proportionally. To achieve consistency in measurement scales across attributes for each user persona, the statistical means of each psychological preference variable for each persona type were Z-transformed and then converted to a percentage scale to represent weights. Summarizing the above label information and naming each user persona based on the mean values of characteristic factors in Table 7, where parts involving proportions in demographic attributes and usage behavior attributes only list those above 10%, the results are shown in Table 8 .

5 User Persona Description and Discussion

Based on the characteristic factors of user personas drawn in Table 8, the key features of each user persona are summarized and described as follows:

5.1 Characteristics of Initial Participation-Type Users

Access convenience, identification guidance, cloud sharing, and conformity participation are the prominent features of the initial participation-type user persona. This indicates that such users remain at the basic function usage stage of the mobile library APP. They have good user experience and perception regarding resource access and identification guidance within the APP. Although they have installed the APP client, they have not yet deeply experienced various function modules. This persona group is concentrated among freshmen and sophomores, with more liberal arts majors and no gender ratio difference. From the perspective of access pathways, over half of users still access through WAP

web pages. Based on such access behaviors, improving user activity within the APP, preventing user attrition, and promoting transformation to mature users through functional perception and recognition are essential.

5.2 Characteristics of Resource Acquisition-Type Users

Resource acquisition-type users have clear resource demands, high requirements for device performance, good perception of librarian service quality, and high expectations for prizes in offline promotion activities. This persona group has a higher proportion of female users and teachers, is concentrated in liberal arts majors, shows high daily access frequency, and mostly uses APP access methods. As they view the mobile library as a new pathway for literature resource acquisition, they are proficient in APP functions such as collection inquiry, book retrieval, and journal searching, which also raises their psychological demands for device performance. Maintaining the activity of such users can be achieved by improving APP device compatibility and functional usability, while stimulating their potential needs for video courses, information customization, and electronic newspapers.

5.3 Characteristics of Omnimedia Reading-Type Users

Omnimedia reading-type users have strong dependence on network speed and are skilled at using the mobile library APP for omnimedia reading. They know how to proficiently obtain subscription information from various information sources and frequently browse audio books, video courses, personalized information subscriptions, and electronic newspapers during fragmented time, while rarely searching for discipline-related professional literature. They equate mobile library usage with other content provider APPs, do not blindly follow trends in APP usage, and are still exploring other function modules. This user type is concentrated among junior and senior undergraduate students, with a low proportion of graduate students, distributed across liberal arts, science, and engineering majors. They show high frequency of multiple daily accesses and a high proportion of multi-terminal device access.

5.4 Characteristics of Mature Users

Mature users show high mean values in user experience, resource demand, and omnimedia reading factors, and are familiar with various function modules of the mobile library APP. Users are concentrated among senior undergraduate students, with no obvious professional differences, showing high daily or weekly access frequency and the highest proportion of multi-terminal device access. The mobile APP is the main access pathway for such users. The highest-weighted librarian service factor indicates that they have the best experience with librarian interaction and problem-solving during long-term mobile library usage. To retain and maintain such users, it is necessary to timely collect user feedback to continuously improve APP user experience, and develop personalized infor-

mation push and service customization based on user persona labels, allowing users to continuously obtain new perceptions.

6 Research Limitations and Future Outlook

This study attempts to consider and describe the complete picture of university mobile library user needs from the perspective of user personas. Starting from user behavior psychological preferences and drawing on the VALS2 user segmentation method, it constructs a user persona label system for university mobile libraries and empirically identifies four differentiated group personas. Since both demographic attributes and psychological preferences have long-term cumulative properties, the personas drawn in this study are overall in a relatively stable state, presenting the most superficial and most internal label elements of each differentiated group, abandoning the conventional practice of viewing user needs homogeneously, thereby providing comprehensive and detailed user persona characteristics and marketing decision support for university mobile library product marketing.

This study provides a new research perspective for university mobile library user service research and offers some references and suggestions for library product or service marketing practice, but it still has certain limitations: (1) Using questionnaire surveys to obtain user persona label data may result in relatively small and non-diverse user datasets. Although discriminant analysis was used to verify the model's universality, further investigation and collection of user behavior characteristic data from other university mobile libraries are still needed to enhance the usability of user personas in supporting precision marketing services. (2) Using the psychological preference mean of each differentiated group to measure each label weight requires subsequent empirical processes such as user behavior tracking, persona iteration and correction, and massive data verification to test its rationality and effectiveness. Future research should consider combining horizontal and vertical research methods to continuously enrich and improve the theoretical system and practical research of university mobile library user personas.

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