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Case study on the construction path of olfactory space in Jiangsu University Library

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Abstract

Purpose – This article explores the scientific construction of library olfactory space, based on the case of the olfactory space in the Jiangsu University library. It specifically focuses on understanding the interaction between the physical architectural space of the library and users' olfactory perception and behavioral activities, with the ultimate goal of creating a deeply integrated olfactory experience in the Jiangsu University Library.
Design/methodology/approach – In this article, an empirical research method was used to gather perceptions from 30 university student users regarding the library olfactory space and to understand their olfactory preferences and requirements for its construction. Through qualitative analysis of the interview texts, the study identified correlations between user perceptions and elements of the library olfactory space.
Findings – The qualitative analysis of user interview texts and results from the library olfactory space design experiment contributed to the design proposal for the Jiangsu University Library olfactory space. The design proposal for the Jiangsu University Library olfactory space is provided and includes library architecture, activity context, functional services, olfactory experience design and technological applications.
Research limitations/implications – This case study takes the environment, development strategy and user needs of the Jiangsu University Library as its unique research background and as such is not universal or generalizable to other libraries.
Originality/value – This article differs from others by advocating for the innovative architectural spatial design of libraries through olfactory experience, breaking the traditional perception of libraries as solely through visual and auditory senses.

Keywords Academic library, Jiangsu University Library, Library olfactory space, Spatial olfactory design, Qualitative analysis

Paper type Case study

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1. Introduction

Jiangsu University is located in Zhenjiang City, Jiangsu Province, adjacent to Shanghai. As a comprehensive university library, the Jiangsu University Library has always adhered to the concept of "research leading service, service promoting research." Thus, it has extensively and deeply explored the innovative transformation and sustainable development strategies of libraries in the new era, continuously improved its level of comprehensive services and provided a high-quality service guarantee for teaching and research development. The Ministry of Education of the People's Republic of China proposed in its "Work Points for the Higher Education Department of the Ministry of Education in 2023" to explore and promote the creation of future learning centers, effectively utilize the advantages of university libraries, integrate the various learning resources of schools, use the new generation information technology and create a new grassroots learning organization that supports the transformation of learning methods. Embodied learning (Ye, 2014) and embodied reading have emerged as new demands of library users, and the construction of future learning centers that integrate multisensory experiences and contextual integration has become an inevitable trend in library space transformation (Xu, Dong, & Li, 2022).

The Jiangsu University Library plans to establish a library olfactory space project to achieve the organic integration of the development of a future learning center with educational resources and user demands. The olfactory space of the Jiangsu University Library aims to meet users' personalized spatial service needs, creating a cozy atmosphere for experiential and immersive learning and comfortable reading through the humanized, scientific and intelligent design of spatial olfaction. Library olfactory space refers to a tangible spatial form within the library's physical environment, where users engaged in indoor activities can perceive a collection of odors through the human olfactory nervous system and trigeminal nervous system (Gao, 2016). It is constituted by the physical dimension of the building, indoor chemical odors, diverse olfactory perception systems and the resulting olfactory experience. By utilizing the close association between olfaction and emotional experiences, this project enhances the profound perception link between the environment and users' bodies, demonstrating its practical innovations.

This study serves as a preliminary validation and theoretical foundation for the construction of olfactory spaces in the Jiangsu University Library. Its primary objective was to actively explore the logical framework and practical trajectory of library olfactory space construction. Given the dearth of empirical research on olfactory spaces in libraries (Wu & Chen, 2022), it was imperative to synthesize pertinent research on the fundamental principles of spatial olfactory design and elucidate the practical strategies and methodologies employed in other domains. Moreover, through empirical research, this study aimed to integrate user demands into the design process of olfactory spaces in the Jiangsu University Library.

2. Literature review

The impact mechanism of spatial odor on human emotions and behavioral performance (Lemercier-Talbot *et al.*, 2019) provided theoretical support for creating a relaxing, focused and pleasant library environment in the olfactory space project of the Jiangsu University Library. Scientific application of the principles of spatial olfactory design facilitates the creation of an olfactory space that aligns with the environment, services and resources of the Jiangsu University Library, thereby enhancing user satisfaction.

While empirical research in the field of library olfactory space was limited, synthesizing the management strategies of spatial olfactory design in other indoor spaces, such as olfactory marketing (Bone & Jantrania, 1992; Cariou & Wilderjans, 2018), offered valuable insights for contemplating a framework for managing a library olfactory space (Pambo *et al.*, 2018). Therefore, a systematic exploration of spatial olfactory design principles and their applications held significant implications for the successful implementation of the project.

2.1 The impact of spatial odors on user behavior

The mechanism of the impact of odor stimulation on human emotions and behaviors is the theoretical basis for the application of olfactory design. Key research topics included olfactory perception, sense of smell, sensory experience and chemical cues. The key to the generation and existence of olfactory space lies in the chemical stimuli received by the user's olfactory sensory system. It can work synergistically with other sensory elements in the physical environment, such as vision and hearing, to influence the user's emotions, perceptions, habitual behaviors and even activity performance. The study of olfactory perception and mechanism has been discussed in various fields, such as neuroscience, psychology and architectural design (Chebat & Michon, 2003; Morquecho-Campos *et al.*, 2022; Haviland-Jones *et al.*, 2013).

Spatial olfactory design affects emotional perception. The olfactory system's nerves directly enter the brain without passing through the central nervous system (Ni, 2010). Olfaction is the sense most closely linked to contextual memory; the thalamus does not filter information from the olfactory nerve and is more easily formed into memory (Hedner *et al.*, 2010). Library spatial olfactory design is an effective memory cue, as diffusing odors similar to pleasant learning memories in learning spaces stimulates participants' learning performance, and odor stimulation has been found to enhance learning memory (Zhong & Gao, 1992). Although different odors have different mechanisms and expression locations for enhancing the brain's learning ability, they all have benefits in consolidating memory and improving learning ability. Therefore, spatial olfactory design in libraries can subtly influence people's emotional perception and cognitive performance in learning (Gurdian *et al.*, 2022). Analyzing the olfactory preferences and sensory perception needs of users in the Jiangsu University Library, based on the mechanism of spatial odor stimulation, is crucial for constructing an olfactory space that meets the users' in-library activity needs.

2.2 Research of spatial olfactory design

Due to the uncontrollability of odor release and its less intuitive impact than visual or auditory stimuli, the application of spatial olfactory design in architectural spaces has not received widespread recognition. The application of olfactory design in commercial spaces, such as shopping malls (Jin, 2019), hotels (Morrin & Ratneshwar, 2003) and restaurants (Jiang, King, & Prinyawiwatkul, 2014), has been extensively explored. Olfactory marketing strategies provide practical guidance for developing spatial olfactory design in libraries.

The specific application of scents in commercial spaces is called olfactory marketing, which aims to integrate the shopping environment, products, consumer emotions and shopping behaviors to achieve commercial objectives (Vega-Gómez, Miranda-Gonzalez, Pérez Mayo, González-López ÓR, & Pascual-Nebreda, 2020). Scents serve as cues for episodic memory (Smith, Standing, & de Man, 1992), influencing the perception of brands and the overall evaluation of consumer experiences. Orange and lavender scents emitted in dental clinics have been found to alleviate anxiety in female patients (Lehrner *et al.*, 2000, 2005). The aroma of food diffused near restaurant entrances can induce salivary secretion and influence food choices (Proserpio *et al.*, 2019; Boesveldt & Parma, 2021; Morquecho-Campos, de Graaf, & Boesveldt, 2020). The aroma of coffee in cafes and the enticing smell of bread near supermarket entrances utilize the connection between olfaction and gustation to extract influential information from olfactory food cues, guiding dietary decisions. Differences in odor attributes have been linked to overall satisfaction with activities (Johnson, 2011; Yoon, 1997), and when odor design aligns with architectural space strategies, it enhances users' evaluation of the space.

Additionally, the relationship between spatial olfactory design and users' bodily perception follows an inverted U-shaped pattern, with consumers perceiving optimal emotional experiences in moderate retail densities (Michon, Chebat, & Turley, 2005). Models

of emotional cognition can demonstrate the influence of shopping space odors on users' perception (Chebat & Michon, 2003). Therefore, a library olfactory space should focus on meeting the goals of library services and fulfilling users' emotional and cognitive needs during their activities in order to stimulate user interest in library olfactory space and enhance satisfaction with the olfactory service in libraries (Slåtten, Mehmetoglu, Svensson, & Sværi, 2009; Errajaa *et al.*, 2021).

Overall, existing research on spatial olfactory design significantly impacts human emotional experiences and behavior. Scholars have primarily focused on the mechanisms of olfactory stimulation in laboratory environments and the optimization strategies of olfactory design and marketing in commercial settings. Empirical research on olfactory needs in public cultural service spaces such as libraries remains scarce, requiring further exploration and analysis of the mechanisms underlying the impact of spatial design on library users. The research methodologies employed in studying the effects of odor stimuli on learning behavior and cognitive performance in laboratory environments provide valuable references for conducting scientifically based experiments on the impact of olfactory stimuli in libraries.

3. Research methodology

Aimed at the development of the Jiangsu University Library olfactory space project, an empirical study was conducted that integrates embodied experience experiments and user interviews. Guided by the theoretical understanding of how spatial olfactory stimuli impact human emotions and behaviors, this study explores the influence of library olfactory space design on user activities, including learning behaviors and reading experiences, through embodied experience experiments. The goal was to provide objective data for constructing the Jiangsu University Library olfactory space.

Furthermore, drawing on the practical application strategies of spatial olfactory design, users' subjective perceptions regarding the olfactory space of the Jiangsu University Library were obtained through interviews to understand their olfactory preferences and sensory perception needs. The data collected from the interviews were then analyzed using grounded theory, a qualitative research method initially proposed by American scholars Glaser and Strauss (Fei, 2008) to develop theoretical constructs. Focusing on the framework for constructing the olfactory space of the Jiangsu University Library, the interviews' textual content was compared, analyzed and categorized to explore the associations between user demands and the elements of library olfactory space.

Lastly, based on qualitative analysis of user interview data and in conjunction with the experiment results, this study synthesized and consolidated user requirements for the library olfactory space at Jiangsu University, ultimately formulating feasible construction plans for the library olfactory space. The research framework is shown in Figure 1.

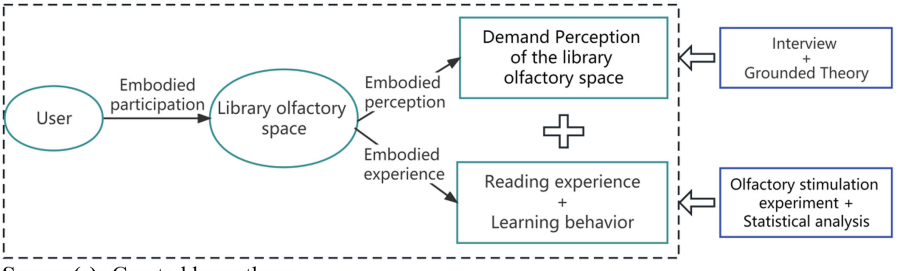

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Figure 1.
Research framework

3.1 Research design

The content design of the demand interview primarily focused on understanding the user requirements for the olfactory space of the Jiangsu University Library. The main objective was to gain insights into the perceptions and demands of university student readers regarding the library olfactory environment. The interview content, which is shown in Table 1, revolved around three key dimensions: the current usage status of the library space, users' odor preferences and their specific requirements for the olfactory space of the library. This approach aimed to provide a comprehensive understanding of the users' needs and preferences and contribute to developing a more tailored and user-centric olfactory space for the library.

The library olfactory space design experiment was based on the theoretical foundation of the effects of olfactory stimulation on behavior and cognition. It employed eye-tracking and physiological signal monitoring as experimental measures to investigate the influence of library spatial olfactory design on users' learning behavior and reading experience. The specific experimental procedures have been outlined in related articles (Su *et al.*, 2023). The experimental equipment is provided in the Appendix.

The feedback interview aimed to understand users' experiential perceptions and evaluations of the library olfactory space design experiment. The interview content is centered on users' evaluations of the simulated library olfactory space experiment. The feedback interview outline primarily included these dimensions: users' olfactory perceptions and subjective experiences regarding learning and reading experiences in the library spatial olfactory design. The feedback interview content is presented in Table 2. Participants' responses to the questions are based on their experiences in the simulated experiment and their understanding of the library olfactory space.

3.2 Participants

All participants in this study were recruited from student readers at the Jiangsu University Library, with a total of 30 individuals (12 males and 18 females) with an average age of 23.27 ± 1.95. Participant information is included in the Appendix. All 30 participants completed the entire research process throughout the study, including a demand interview, a

Table 1.
The contents of the demand interview

Dimension	Interview content
Usage of the library	1. What are your favorite activity areas in the library?
	2. What activity contexts have you participated in at the library?
	3. What functional services do you frequently engage with in the library?
	4. Are you satisfied with the spatial services of the library?
Olfactory preference	5. What are your favorite scents?
	6. What types of fragrance devices do you prefer, such as perfumes or aromatherapy?
	7. Would you like learning spaces or reading spaces with spatial olfactory designs?
	8. What architectural design do you expect for the library olfactory space?
	9. What activity contexts would you like in the library olfactory space?
Demands for the library olfactory space	10. What functional services do you hope to have in the library olfactory space?
	11. What are your preferred odors for the library olfactory space?
	12. What are your preferred methods of releasing scents in the library space?
	13. Will spatial olfactory design affect your satisfaction with the library?

Source(s): Created by authors

Dimension	Interview content
User olfactory perception	1. Have you smelled any specific odors indoors during the experiment? 2. Please describe the changes of the odors you have smelled 3. Please describe the degree of harmony between the odors you have smelled and the library environment
User satisfaction with the library spatial olfactory design	4. How has spatial olfactory design influenced your learning experience? 5. How has spatial olfactory design influenced your reading experience? 6. Are you willing to read or study for extended periods in an environment with spatial olfactory design? 7. Does this experience fulfill your requirements for the library olfactory space? 8. Does the olfactory space affect your satisfaction with the library?

Source(s): Created by authors

Table 2. The contents of the feedback interview

simulated experiment and a feedback interview. The comprehensive participation of the study ensured a more inclusive and representative collection of user perspectives and insights.

3.3 Procedure

The study spanned two months at the User Information Behavior Laboratory of the Jiangsu University Library. Per the task requirements, interviews and experiments were conducted in two adjacent rooms—the interview room and the simulated experiment room. Each research task involved the participation of one individual. The research tasks commenced with a requirement interview, conducted in the interview room, lasting approximately 10 minutes. Before the interview, the researchers introduced the concept and significance of the library olfactory space to participants. Subsequently, participants moved to the adjacent simulated experiment room to undertake the second task: the simulation of library olfactory space, guided by the researchers and lasting approximately 40 minutes. After completing the simulated experiment, participants returned to the interview room for the third task: feedback interviews, which took approximately 10 minutes. The total time each participant spent on the research was approximately 60 minutes.

4. User demands for olfactory space in Jiangsu University Library

Qualitative analysis of the user interviews revealed that the demands for the Jiangsu University Library olfactory space can be categorized into five aspects: library architecture, activity context, functional service, olfactory and technological application.

4.1 Demands for library architecture

The Jiangsu University Library boasts a grand and imposing architectural design. Its indoor space is divided into office areas and reader activity zones, catering to library staff management and user engagement needs. The reader activity area is further divided into static and dynamic zones. The static zone features long desks and tall bookshelves, creating a serious and focused studying ambiance. During exam weeks, students prefer the static reading room. One participant mentioned, "The reading room has been my go-to place during intense study sessions." On the other hand, the dynamic activity area is characterized by

discussion tables and long sofas, providing users with spaces for communication, relaxation and collaborative work. Participants stated, "The long sofa is my favorite spot to unwind." The dynamic space adds flexibility and fluidity to the library, fostering a relaxed and well-lit learning atmosphere. The Jiangsu University Library's interior is well-organized, and besides considering the type of activity, users also consider factors such as lighting, aroma and social distance when choosing an area. Statements like "I prefer the sunny spots, as they brighten my mood," "I usually sit near the entrance for better air circulation" and "I prefer individual small tables and chairs" all underscore the significant impact of environmental elements on user satisfaction with their library experience.

Compared to the conventional rigid layout that exudes a severe tone, the simulated laboratory for this experiment adopted a more relaxed approach with small round tables and low bookshelves. The spacious and unconfined setting has garnered favor from many users, with some expressing their desire to "want to have the chance to read for an entire day in such a library environment." To develop olfactory space in the Jiangsu University Library, users desire an expansive, well-lit and comfortable environment that fosters a smooth, tranquil and pleasant learning atmosphere.

Student users are increasingly concerned about the impact of environmental elements such as lighting, temperature, humidity, comfortable seating and social distancing on their experience. The architectural spatial design of the library needs to explore how to enhance the user experience by focusing on the relationship between the built environment and people. This design will ultimately lead to the improved service quality and attractiveness of the library.

4.2 Demands for library activity context

As the main study space for students, the library offers a typical environment for independent learning and research exchange. University students consider the library their preferred study place, where they have favorable conditions for self-directed learning and exam preparation. This is true especially during exam months: as one participant said, "I usually arrive at the library entrance at 7 am, waiting in line for it to open." The library provides a conducive learning atmosphere that helps students concentrate and better prepare for exams. Beyond providing books and study resources, the library is a social and interactive hub. Each floor has discussion areas, allowing students to study together and exchange ideas. Students can discuss issues and share thoughts in these areas. However, the severe existing learning environment in the library falls short of meeting the users' needs for a comfortable, relaxing and inclusive study environment. One student said, "The intense learning atmosphere in the library often puts much pressure on me."

By utilizing the subtle influence of scents on emotions, the library can create a more pleasant environment to help users relax and enter a better state for learning. Regarding the construction of the olfactory space at the Jiangsu University Library, students expressed, "In the spatial olfactory reading room, I can study all day without feeling tired." Natural aromas can alleviate the tense exam atmosphere, and the comfortable olfactory experience resonates emotionally with users. Introducing different scents and fragrances can have varying effects in different scenarios, such as enhancing focus or inducing relaxation: "The experimental environment is very comfortable, and time flies by while reading." Leveraging the subtle impact of scents on emotions enhances users' immersive reading experience, thereby increasing their satisfaction with the reading experience.

Users' demands for library activity scenarios have evolved from tense and focused study environments to diverse, personalized, comfortable and experiential environments. Therefore, library spatial design needs to incorporate environmental elements that stimulate users' multisensory systems to meet the diverse needs of users for library activity scenarios.

4.3 Demands for library functional services

The Jiangsu University Library offers abundant resources for borrowing, space services and support for academic disciplines and research. Among them, space services like reading rooms, electronic reading rooms, discussion rooms and leisure areas provide physical venues for users' knowledge and educational activities. With the new age of thriving digital technology, users' demands for library services have evolved from functional to experiential needs. Existing space services have relatively weak interaction with users' mental perception, and users expect the library to create diverse space experiential services.

During the simulation experiment, scents dispersed in the space were captured by the olfactory sensory system, stimulating the emotional system and significantly impacting reading experiences and learning performance. One user expressed in a feedback interview, "While doing the questions, suddenly smelling the scent of mint, my previously nervous mood instantly relaxed." Analysis of the simulation experiment revealed that scents of lemon and mint in the learning environment enhanced attention during the learning process and alleviated the tension caused by the study pressure, thereby regulating stress during learning. The design of library space scents also strengthened the connection between users' learning behavior and the environment. Regarding the learning experience, participants mentioned, "The refreshing and natural scent of osmanthus makes me enjoy my reading time" and "The faint aroma of gardenia is a clean and refreshing fragrance that I like." Participants expressed that the pleasant scent environment enhanced their satisfaction with the reading experience, and they look forward to implementing olfactory space projects in the library to have more experiential feelings.

Users expect the library's functional services to be more diverse and hope that the library becomes a multisensory, comfortable and pleasant space for learning and communication.

4.4 Demands for user olfactory perception

The preferences, olfactory perception abilities and expectations of library staff and reader groups regarding olfaction are essential factors in implementing a user-centric approach to library space design. The olfactory design of library spaces can have a profound impact on users' sensations and experiences. Through user needs interviews, it was found that compared to male users, female users pay more attention to olfactory experiences in daily life and use scented products more frequently. However, for library space odors, subtle and fresh scents are favored by all user groups. Scents like citrus, fresh grass and fruits are perceived as creating a relaxed and comfortable reading environment.

Since learning and reading are routine activities in the library, aligning the odor design with the demands of these activities can enhance users' sense of belonging and satisfaction. Users expressed their desire for an olfactory space that "creates a cozier atmosphere for reading" and "promotes a relaxed study ambiance," highlighting the unique aspects of the library environment. Stimulating scents like peppermint are suitable for study environments, while soothing scents like lily fit reading environments. Calming scents like lemon or lavender can help library users concentrate and relax.

User demands for olfactory design in library spaces are crucial for enhancing user experience and satisfaction. A well-matched odor design that aligns with users' olfactory preferences and in-library ambiance can provide a comfortable, focused and enjoyable learning and reading environment. It is important to consider users' olfactory perception abilities as well. Library odor design should be balanced, especially in high-traffic areas, by opting for neutral or widely appreciated scents to ensure most users enjoy a comfortable ambiance.

4.5 Demands for technological application

The management principles and technological applications of library administrators and spatial architects are essential factors in creating and managing olfactory spaces in libraries.

It encompasses the conceptual frameworks, technical provisions and operational mechanisms related to managing olfactory spaces in libraries. Within this context, the technical elements of library olfactory spaces include odor devices, release mechanisms and the correlation between odors and spatial configurations.

Over time, the concentration of odors tends to diminish. Prolonged exposure to a specific odor within the library environment can significantly impact the olfactory perception of library users. Given the essential nature of respiration, the olfactory perception of users within library buildings is an involuntary and uninterrupted process. Consequently, users desire the authority to control the activation of odor-release mechanisms, stating, "I wish to have the ability to access the switch at any given time." Therefore, the release mechanisms within the olfactory spaces of libraries need to be supported by technological means to ensure the stable confinement of specific odors within defined spatial boundaries, preventing excessive diffusion. Additionally, empowering users to control these mechanisms at their convenience fosters a human-centric library experience environment.

5. Design of olfactory space in Jiangsu University Library

The olfactory space in the Jiangsu University Library is currently in the project preparation stage. In the future implementation process, the design and construction work will be organized and conducted according to the findings of this research and aim to meet the personalized spatial service needs of library users. The olfactory space of the Jiangsu University Library will follow the user-centered libraries development concept, aiming to improve the embodied experience between the library space and users and adhering to the equalization of user experience. Focusing on the library's resources, services and staff capabilities, an olfactory experiential environment was constructed that meets the users' activity needs in the library. By taking into account the users' requirements for the olfactory space of the library and considering the relationships among the five construction elements of (1) library architecture, (2) activity context, (3) functional services, (4) olfactory demands and (5) technological applications (Figure 2), the library elements, user elements and technological elements are scientifically incorporated into the practical implementation of olfactory space.

Therefore, the olfactory space of the Jiangsu University Library, based on the users' cognitive needs for the library olfactory space, was designed with personal activity areas and communication and discussion areas in the open activity zone, meeting the users' diverse

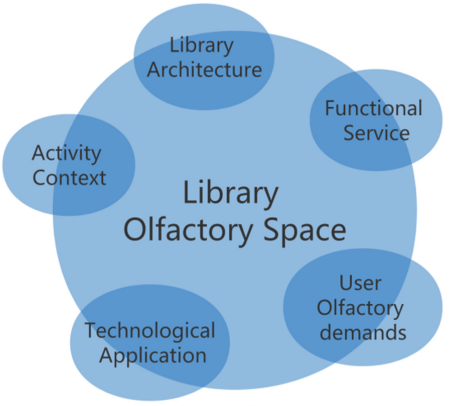

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Figure 2.
Construction elements of library olfactory space

demands. Furthermore, considering the users' needs for olfactory perception and technological applications, it will allow users to choose suitable scents for different activity contexts through the intelligent connection of IoT and terminal release devices.

5.1 Design of library architecture

The olfactory space in the library will utilize the olfactory sensory functionality of the human body, employing innovative spatial divisions and segmentation to evoke imaginative and extended cognitive experiences for readers. In delineating different areas within the olfactory space, the design will break free from predefined spatial constraints, dividing and segmenting the open and shared spaces to meet users' demands for a flexible and relaxed learning atmosphere.

The entire activity area will be located near windows and benefit from ample natural lighting and a bright and transparent ambiance. Glass and blinds will partition the space, creating distinct spatial atmospheres that guide readers' activities in different areas. The open space will include individual study areas with small round tables, enhancing the fluidity of spatial activities. The shared space, enclosed by transparent glass, will incorporate long discussion tables and low bookshelves, facilitating communication and collaborative research.

5.2 Design of activity contexts

The olfactory space in the Jiangsu University Library will cater to students' autonomous learning, reading and discussion activities, enhancing user satisfaction during their library visits.

The discussion areas within the library olfactory space are designed to meet users' needs for collaborative, communicative and creativity-inspiring activity scenarios. The olfactory design, in harmony with visual elements, will create a bright, clean and comfortable overall environment, providing students with a pleasant space for academic discussions and knowledge sharing.

The autonomous activity areas in the library olfactory space will offer users a comfortable and relaxing environment for independent learning. Stimulating scents like mint and lemon will enhance concentration and improve learning outcomes. During exam preparation, prolonged study sessions may cause fatigue and stress. Therefore, the mild scent of lilies will help to create a relaxed study atmosphere, enabling students to alleviate academic pressures and exam anxieties, thus better preparing for exams. Additionally, a focused and serene reading environment will be achieved by using calming and tranquil scents, fostering a relaxing and enjoyable reading atmosphere that helps users unwind and enter a better reading state, ultimately enhancing their reading experience satisfaction.

The library olfactory space will cater to various activity scenarios, avoiding strong odors, providing a comfortable and soothing sensory experience and coordinating with visual elements to create an enjoyable and beneficial learning environment.

5.3 Design of functional services

The open autonomous learning and collaborative discussion areas will conform to the experiential learning context. The layout will cater to individual autonomous learning and team-based collaborative communication needs, enhancing the flexibility and fluidity of in-library activities. The open space will provide an olfactory playback device embedded in the tabletop, offering a variety of scents that will create a comfortable, soothing ambiance conducive to individual learning and reading contexts. Users will be able to select scent types according to their preferences independently. The shared space will offer lively and

stimulating scent selections for interactive social activities. It will also suit seminars and conferences, creating a comfortable and vibrant atmosphere that stimulates collaborative social learning, encourages creativity and supports knowledge creation.

The careful combination of space services and scents will allow users to not only enjoy new experiences and personalized services but also encourage their active engagement in scene transitions and deep utilization of functionality, thus fully unleashing the efficacy of the olfactory space in the library. By incorporating olfactory perception characteristics into knowledge sharing and immersive learning, the scent diffusion system, in conjunction with the library's spatial characteristics, will enhance emotional communication between readers and the architectural space while improving the overall activity experience.

5.4 Design catering to user olfactory demands

The project construction of olfactory spaces in libraries follows the human-centered design development concept, catering to the basic needs of the public. Incorporating users' preferences for olfactory perception and scent habits into the design ensures these spaces' adaptability and autonomy. Through olfactory design, a space that promotes comprehensive interaction among readers is created, enhancing their practical engagement and experiential satisfaction and fostering a positive emotional and cognitive interaction with the library. Olfactory design includes both foundational scents and customizable personalized scents. The six foundational scents at the Jiangsu University Library will include lime, peppermint, lily, citrus, books and ink, suitable for different activity contexts.

Based on user interviews and experimental results from olfactory design in library spaces, the foundational scents are selected. A peppermint scent in the library olfactory space has been recognized for its positive effects on learning behavior and promoting learning performance, helping readers better focus on their studies. The comfort provided by lily and citrus scents can enhance users' pleasant emotions, allowing readers to feel relaxed and joyful, making them suitable for reading and discussion contexts. The scents of books and ink can evoke readers' fond memories of learning and reading, deepening their cultural awareness of the library and aligning with users' consensus on the purpose of the library.

In addition to foundational scents, customized personalized scents will be another highlight of the library olfactory space project. Users can choose scents based on their preferences and adjust them using scent players. This personalized design will increase users' sense of involvement and satisfaction, allowing each individual to find the most suitable scent for themselves in the library, further enhancing their experience.

5.5 Design of technical application

Selecting scent diffusion devices and scent materials is a technical measure for implementing the library olfactory space. In this regard, the M-Series Digital Scent Player and scent capsules from the Fragrance Kingdom brand were chosen. The scent player supports the playback of six digital scents and is equipped with a personal version of the digital scent editor mini-program, allowing users to customize and blend scents to meet their needs for different spatial atmospheres in learning, reading and discussion. The frequency of scent release can be set periodically, cycling within the designated period. Users can adjust the types of scents and the duration of scent release based on their preferences and activity scenarios.

Furthermore, scent capsules are materials used with the digital scent player. Each scent capsule has a lifespan of approximately 16 hours, allowing users to enjoy a long-lasting and pleasant scent continuously. The design of the scent capsules is sophisticated, making them easy to replace and install, facilitating the switching of different scents to adapt to various scenes and needs.

In terms of cost, the unit price of the M-Series Digital Scent Player is ¥799, and the unit price of scent capsules is ¥79. The Fragrance Kingdom's M-series digital scent player and capsules are relatively cost-effective, considering budget constraints. The versatility of the scent player allows it to meet various needs, reducing the cost of purchasing additional devices. The long lifespan of the scent capsules reduces the frequency and cost of replacement.

6. Conclusions

The olfactory space in the Jiangsu University Library influences users' emotions through olfactory stimulation, enhancing the connection between library architecture and user experience. Library olfactory space meets users' demands for multisensory experiences and integrated learning environments, increasing their engagement and excitement for library cultural activities.

This research focuses on the spatial olfactory design of libraries and its impact on university library users' learning behavior and reading experiences, aligning with the fundamental requirements of spatial services in university libraries. In future research, we will further explore the correlation between olfactory experiences and users' engagement in communication and social activities within the library, facilitating social interactions and knowledge sharing among users, ultimately enriching their learning and personal development experiences.

References

Boesveldt, S., & Parma, V. (2021). The importance of the olfactory system in human well-being, through nutrition and social behavior. *Cell and Tissue Research*, *383*, 559–567.

Bone, P. F., & Jantrania, S. (1992). Olfaction as a cue for product quality. *Marketing Letters*, *3*, 289–296.

Cariou, V., & Wilderjans, T. F. (2018). Consumer segmentation in multi-attribute product evaluation by means of non-negatively constrained CLV3W. *Food Quality and Preference*, *67*, 18–26.

Chebat, J., & Michon, R. (2003). Impact of ambient odors on mall shoppers' emotions, cognition, and spending. *Journal of Business Research*, *56*, 529–539.

Errajaa, K., Legohérel, P., Daucé, B., & Bilgihan, A. (2021). Scent marketing: Linking the scent congruence with brand image. *International Journal of Contemporary Hospitality Management*, *33*, 402–427.

Fei, X. (2008). The methodological research of grounded theory: Elements, research process, and evaluation criteria. *Public Administration Review*, *1*(3), 23–43.

Gao, H. (2016). On McLuhan's auditory space and visual space: A new interpretation of McLuhan's media thought. *International Journalism*, *38*, 79–93.

Gurdian, C. E, Torrico, D. D., Li, B., & Prinyawiwatkul, W. (2022). Effects of tasting and ingredient information statement on acceptability, elicited emotions, and willingness to purchase: A case of pita chips containing edible cricket protein. *Foods*, *11*, 337.

Haviland-Jones, J. M., Hudson, J. A., Wilson, P., Freyberg, R. J., & McGuire, T. (2013). The emotional air in your space: Scrubbed, wild or cultivated? *Emotion, Space and Society*, *6*, 91–99.

Hedner, M., Larsson, M., Arnold, N., Zucco, G. M., & Hummel, T. (2010). Cognitive factors in odor detection, odor discrimination, and odor identification tasks. *Journal of Clinical and Experimental Neuropsychology*, *32*, 1062–1067.

Jiang, Y., King, J. M., & Prinyawiwatkul, W. (2014). A review of measurement and relationships between food, eating behavior and emotion. *Trends in Food Science and Technology*, *36*, 15–28.

Jin, M. (2019). Scent induction: The application of olfactory design in stores – a case study of MUJI. *Art and Design (Theory)*, *2*, 45–46.

Johnson, A. J. (2011). Cognitive facilitation following intentional odor exposure. *Sensors*, *11*, 5469–5488.

Lehrner, J., Eckersberger, C., Walla, P., Pötsch, G., & Deecke, L. (2000). Ambient odor of orange in a dental office reduces anxiety and improves mood in female patients. *Physiology and Behavior*, *71*, 83–86.

Lehrner, J., Marwinski, G., Lehr, S., Johren, P., & Deecke, L. (2005). Ambient odors of orange and lavender reduce anxiety and improve mood in a dental office. *Physiology and Behavior*, *86*, 92–95.

Lemercier-Talbot, A., Coppin, G., Cereghetti, D. M., Porcherot, C., Cayeux, I., & Delplanque, S. (2019). Measuring automatic associations between relaxing/energizing feelings and odors. *Food Quality and Preference*, *77*, 21–31.

Michon, R., Chebat, J., & Turley, L. W. (2005). Mall atmospherics: The interaction effects of the mall environment on shopping behavior. *Journal of business research*, *58*, 576–583.

Morquecho-Campos, P., de Graaf, K., & Boesveldt, S. (2020). Smelling our appetite? The influence of food odors on congruent appetite, food preferences and intake. *Food Quality and Preference*, *85*, 103959.

Morquecho-Campos, P., Hellmich, I. M., Zwart, E., de Graaf, K., & Boesveldt, S. (2022). Does odour priming influence snack choice? – An eye-tracking study to understand food choice processes. *Appetite*, *168*, 105772.

Morrin, M., & Ratneshwar, S. (2003). Does it make sense to use scents to enhance brand memory?. *Journal of Marketing Research*, *40*, 10–25.

Ni, D. (2010). *Olfactory basics and clinical practice*. Beijing: People's Health Publishing House.

Pambo, K. O., Okello, J. J., Mbeche, R. M., Kinyuru, J. N., & Alemu, M. H. (2018). The role of product information on consumer sensory evaluation, expectations, experiences and emotions of cricket-flour-containing buns. *Food Research International*, *106*, 532–541.

Proserpio, C., Invitti, C., & Boesveldt, S., (2019). Ambient odor exposure affects food intake and sensory specific appetite in obese women. *Frontiers in Psychology*, *10*. doi:10.3389/fpsyg.2019.00007.

Slåtten, T., Mehmetoglu, M., Svensson, G., & Sværi, S. (2009). Atmospheric experiences that emotionally touch customers A case study from a winter park. *Managing Service Quality*, *19*, 721–746.

Smith, D. G., Standing, L., & de Man, A. (1992). Verbal memory elicited by ambient odor. *Perceptual and motor skills*, *74*(2), 339–343.

Su, W. C., Yu, Y. Y., Lu, Z. P., Liu, G. F., & Wu, J. R. (2023) (In press). *The spatial olfactory impact mechanism on university library users' learning and reading behavior*. Harbin: Library Construction. Available from: http://kns.cnki.net/kcms/detail/23.1331.G2.20230203.1108.003.html

The key points of the Higher Education Department of the Ministry of Education's work in 2023. Available from: http://www.moe.gov.cn/s78/A08/tongzhi/202303/t20230329_1053339.html/ (accessed 20 July 2023).

Vega-Gómez, F. I., Miranda-Gonzalez, F. J., Pérez Mayo, J., González-López ÓR, & Pascual-Nebreda, L. (2020). The scent of art. perception, evaluation, and behaviour in a museum in response to olfactory marketing. *Sustainability*, *12*(4), 1384.

Wu, M., & Chen, M. (2022). A discussion on the olfactory design of library spaces. *Journal of University Libraries*, *40*, 44–51.

Xu, J., Dong, X., & Li, X. (2022). Reflections and practices on the construction of future learning centers in university libraries. *Journal of University Libraries*, *40*, 12–18.

Ye, H. (2014). The theoretical analysis of the concept of embodiment. *Acta Psychologica Sinica*, *46*, 1032-1042.

Yoon, C. (1997). Age differences in consumers' processing strategies: An investigation of moderating influences. *Journal of Consumer Research*, *24*, 329–342.

Zhong, Y., & Gao, D. (1992). The experimental study on the influence of ambient odor on memory performance accompanying learning. *Psychological Science*, *01*, 5.

Appendix

Source(s): Created by authors

Figure A1. Mobile eye tracker and the Spirit-10 MARK II wireless physiological feedback device

Olfactory group	ID	Gender	Age
Gardenia	101	Female	24
	102	Female	21
	103	Female	24
	104	Male	24
Osmanthus	401	Male	23
	402	Female	22
	403	Male	20
	404	Female	25
	405	Female	20
Lemon	501	Female	24
	502	Male	20
	503	Female	24
	504	Male	22
Odorless	001	Male	25
	002	Female	24
	003	Female	24
	004	Male	26
White Tea	201	Female	24
	202	Female	24
	203	Female	23
	204	Male	21
Peppermint	301	Female	26
	302	Female	24
	303	Male	27
	304	Male	23
	305	Female	25
Lily	601	Male	22
	602	Male	20
	603	Female	21
	604	Female	26

Source(s): Created by authors

Table A1. Statistical information of participants

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Yingying Yu is a graduate student majoring in library and information science at the Institute of Science Technology and Information of Jiangsu University. Her recent research focuses on library space and environmental psychology. She has presented at conferences in China. Her research has been published in journals including *Library Development, Journal of Library and Information Science in Agriculture*.

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