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Noise in Maternity Wards: A Research on Its Contributors and Sources

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Abstract: This research aimed to investigate the major user behavior patterns of noise sources in healthcare environments and summarize such information as evidence that can inform the design of maternity wards for indoor noise control and patients' well-being. Field investigations were conducted to identify users' behaviors as the major contributors of noises in the maternity wards of a typical hospital. A control experiment was set to test the feasibility of a noise control system that consisted of smart bracelets, mobile terminals, and monitors. Comparative studies were designed for statistical analysis of patients' sleep quality and satisfaction. Finally, a follow-up interview was conducted among the experts who were from the fields of healthcare environment design, medical treatments, and hospital administration to shed an insight into their concerns on the findings. The enclosed waiting areas, instead of open ones that were often seen in hospitals, around the entrances of operation rooms, were considered as the appropriate design strategy for maternity wards in China. Such a design could keep patients from being exposed to the excessive noises generated by visitors during nighttime, although it would occupy the floor area of wards and lead to a reduction of beds.

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Moreover, the statistical information of patients' behaviors could be used to moderate visitors' behaviors. It was necessary to include user behavior information in building information management and then make a good trade-off between the proportions of wards and enclosed waiting rooms in order to achieve a balance of medical efficiency and environmental satisfaction.

Keywords: user behavior, information management, healthcare environment, noise control, evidence-based design

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Introduction

The design of a healthcare environment needs to contribute to the process of healing rather than being a place where medical treatments take place (Department of Health, 2014; Hamilton & Watkins, 2009; Phiri & Chen, 2014). With the impacts of the physical environment of hospitals (e.g., luminous, acoustic, and wind environments), patients exhibit different behaviors and status, which reflect in their recovery rates and satisfaction (Phiri & Chen, 2014). Previous research on evidence-based design indicated that the acoustic environment was the most important factor that affected patients' environmental satisfaction and healthcare outcomes (Qin et al., 2011). The indoor noise level below 55 dBA can effectively promote patients' healing process and relieve their postoperative pains and negative emotions (e.g., anxiety, pressure, and sadness; Ban et al., 2016; Bayo et al., 1995; Minckley, 1968). However, patients are easily exposed to excessive levels of noises which often negatively influence their recovery and well-being in hospitals (Xie et al., 2009). For pregnant and postpartum women, the excessive noise levels would affect them both physiologically and psychologically. For example, these patients, especially those with pregnancy complications, might suffer from vasoconstriction of sympathetic nerve and increases in blood glucose, blood pressure, and heart rate (Li, 2015; Yang et al., 2019). In addition, a clinical statistical study from 2006 to 2010 claimed that there might be a possible relationship between long-term noises and the risk of preterm birth (Smith et al., 2020).

A good scope of indoor noises should be maintained around 50–60 dBA, but user behaviors (e.g., communications, crying, laughing, snoring, ringing of a phone, and walking with spikes) which are defined as the major noise contributors in wards at night would produce noises to a level of 60–80 dBA (Ban et al., 2018; Whitfield, 1975; Xie & Kang, 2012). As indicated in previous studies, it was frequently noticed that the noise levels in wards exceeded

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the benchmarking standard as set by the World Health Organization (WHO) with more than 20 dBA (MacKenzie & Glabrun 2007; Ryherd et al., 2008; Xie & Kang, 2012; Xie et al., 2009, 2013). In China, the national design guidance for healthcare buildings (GB/T 51153-2015) indicates that the acceptable indoor noise levels in a hospital should be below 55 dBA. However, the real-life situation of the acoustic environments of hospitals is not optimistic–the average indoor noise level of Chinese hospitals is above 60 dBA (Bai et al., 2019; Ministry of Housing Urban and Rural Development, 2015; Xie & Deng, 2017). For example, the volume of noises in outpatient waiting areas can reach 71 dBA (Tang et al., 2020; Xie & Deng, 2017). Likewise, an on-site measurement for the obstetrical department of a general hospital in 2019 showed that the average noise levels of predelivery rooms, maternity wards, and operation rooms were, respectively, 60.5 dBA, 62.2 dBA, and 70.6 dBA due to visitors' behaviors (Li, 2015; Yang et al., 2019). **It is necessary to adopt appropriate design strategies that can maintain the noises generated by users' behaviors in the maternity wards (i.e., patients, visitors, and medical staff) to a satisfied level and thereby prevent pregnant and postpartum women from unnecessary harm**.

This research aims to investigate the major user behavior patterns that may become noise sources in maternity wards and to propose potential solutions that can control the major noises produced by visitors at night. Previous studies regarding noise source measurements of healthcare environments in China were mainly focused on the influence of noises from different users at a hospital level (Li, 2015; MacKenzie & Glabrun, 2007; Minckley, 1968; Xie et al., 2009). There is a lack of studies focusing on specific acoustic environmental characteristics of maternity wards. **This research considers user behaviors as important building information that can be used to inform the design and management of healthcare environments**. Based on on-site measurements and statistical analysis, the findings from this

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research will provide evidence on users' satisfaction of acoustic environments that can inform the design of general hospitals' maternity wards in China.

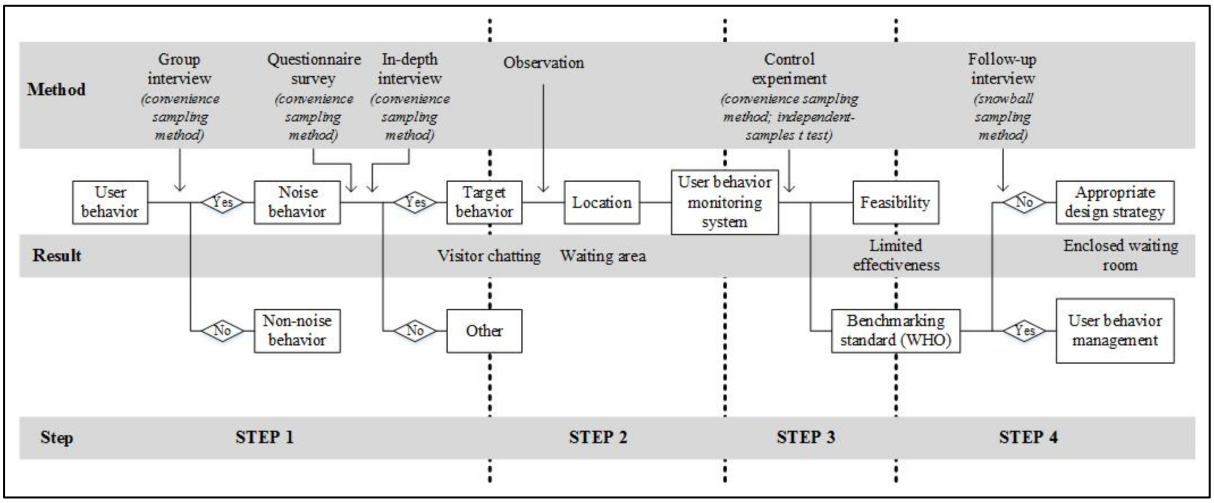
Methods

Study Design

This research presents a series of investigations and experiments conducted in the maternity wards of a typical general hospital in China (Figure 1). Field investigations, including interviews, questionnaire surveys (Step 1), and observations (Step 2), were conducted in order to identify the major use behaviors resulting in noises in maternity wards. A control experiment (Step 3) was conducted to explore the feasibility of using a user behavior monitoring system (i.e., smart bracelets–mobile terminals–computers–monitors) to change visitors' behaviors and thereby control the noise levels. A follow-up in-depth interview (Step 4) was finally conducted to discuss the design strategies for noise control in maternity wards and operation rooms.

Figure 1

Scheme of the study design.



It is important to note that all investigations and experiments were conducted in a general hospital built in 2012 in a prefecture-level city in China. The floor area of this hospital is around

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147,000 m^2 (1,582,294.83 ft^2). It includes a complete obstetrical department, including maternity wards, predelivery rooms and operation rooms, with 70 beds for inpatients and a day/night shift system for more than 60 doctors and nurses.

Step 1: Interviews and Questionnaire Surveys

Some sounds are considered as noises because of their undesirable impacts on people, such as disturbing patients' rest or affecting their emotions (Ban et al., 2018). Such noises should be filtered in a healthcare environment. To identify the major noise sources, social research methods, including interviews and questionnaire surveys, were applied. A group interview was conducted on-site with a small group of inpatient representatives. The convenience sampling method was applied for this group interview. In total, 12 participants, including pregnant and postpartum women, were invited randomly based on the principle of voluntariness. They were asked to discuss and indicate the noises and relevant behaviors that might affect their hospitalization and rest during nighttime. This group interview lasted 1.5 hr, and unstructured interview methods were applied with a brief topic–"what behaviors in the maternity wards are noisy and make you feel uncomfortable."

The first round of questionnaire surveys was designed to evaluate inpatients' attitudes about the selected behaviors that often resulted in noises in the maternity wards of a general hospital. A 5-point Likert-type-scale method was applied to quantitatively measure the relative influence of these noise behaviors, including *not at all influential*–1, *slightly influential*–2, *somewhat influential*–3, *very influential*–4, and *extremely influential*–5. The survey lasted a week, when there were 102 inpatients in all maternity wards of the general hospital. They were defined as the sampling unit. In total, 102 questionnaires were thereby distributed to all those inpatients, and finally, there were 37 usable ones that were collected with a response rate of

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36.3% (Bryman, 2014). As the target population consisted of pregnant and postpartum women who might be unwilling to respond due to pain and anxiety, the response rate was acceptable and effective.

An in-depth interview was conducted to verify the findings from the first-round questionnaire survey and further identify the user behaviors of major noise sources. According to the convenience sampling method, another seven inpatient representatives were invited individually to share their opinions on the questionnaire results and noise behaviors. Each interview lasted 10 min, and the participants were asked to evaluate the results of questionnaires and provide suggestions on solving the negative impacts of noises in maternity wards. The key words that were repeatedly used by the interviewees to describe the noise behaviors (e.g., "chatting," "crying," and "footstep") were extracted from the records in order to gain an insight into the opinions of inpatients about the influence of noise behaviors.

Step 2: Observations

The observations were arranged to locate where the major noise behaviors occurred frequently in the maternity wards of hospitals. Based on the attitudes of interviewees, researchers attempted to identify the locations where the most influential noise behaviors happened. The observations lasted three nights. It was found that the main location with excessive noise levels in the obstetrical department was the waiting areas. To ensure the efficiency of medical treatments, waiting areas for visitors were usually designed as an open space near the entrances of predelivery rooms and operation rooms surrounded by wards. Based on the case studies of general hospitals in China, it was noticed that such a design was a typical pattern of maternity wards and operation rooms for some prefecture- and county-level hospitals because this spatial layout would save therapeutic spaces and increase the quantity of beds.

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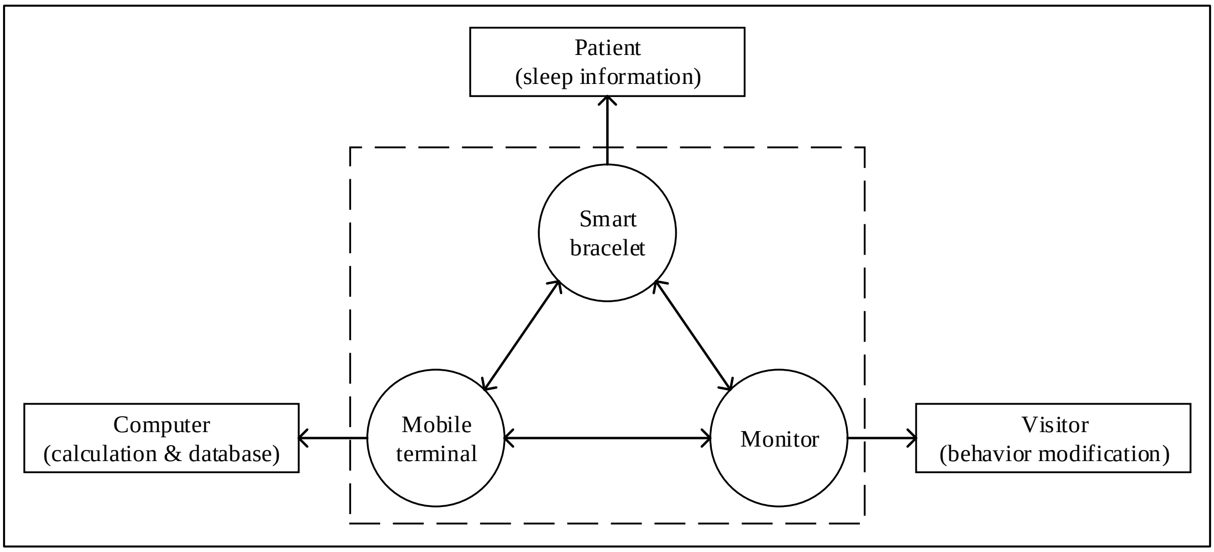
Moreover, such a design would improve the efficiency of contacting the family members of intraoperative patients, in case there was an emergency during the operation process.

A user behavior monitoring system was proposed, which intended to record inpatients' behaviors of rest and sleep into information and then use such information to moderate the selected noise behaviors of visitors (Figure 2). Inpatients' sleep information, including sleep rates (i.e., the percentage of sleeping inpatients) and quality (i.e., wake-up frequency) at night, was statistically analyzed in the computer. Their sleep rates, together with the volume of existing noise levels and the benchmarking standard 55 dBA from the WHO, were displayed to remind the relevant users of waiting areas for their behavior modification. The monitor was set where the target noise behaviors frequently occurred.

Figure 2

Workflow of a user behavior monitoring system in this research.



Step 3: A Control Experiment

A control experiment was designed to test the feasibility and effectiveness of the user behavior monitoring system. This control experiment lasted four weeks. Every day, the

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experiment remained five inpatient representatives who were randomly selected to wear smart bracelets (Huawei Band 3 and Band 4 were applied in this experiment). Based on the convenience sampling method, in total, 43 inpatients were selected as samples during the experimental period (i.e., 28 days), whose sleep rates were recorded based on the data achieved from smart bracelets (Table 1). All these inpatients measured were postpartum women. Pregnant inpatients were excluded from this experiment, as they might give birth at any time and the sterilization standards required them to remove the bracelets and any accessories.

Table 1

The schedule and sample quantity of the control experiment

Category	Week 1	Week 2	Week 3	Week 4	Total
Sample quantity of experimental group	11	0	10	0	21
Sample quantity of control group	0	10	0	12	22

The information of participants' sleep rates was recorded by computer from 08:00 pm to 08:00 am (i.e., a night defined by this research) every day. It could be read by the researchers from the mobile terminals (i.e., cell phones and tablet computers). For the experimental group, the information was displayed in a monitor as a reminder (08:00 pm–08:00 am) to the inpatients' family members and other others who were the potential noise producers. The monitor was set in the waiting area where the target noise behaviors frequently occurred to remind visitors to keep quiet at night (Figure 3). A digital sound level meter (Benetech GM1356, highly accurate with ± 1.5 dBA) was used to record the real-time on-site noise levels. The frequency of inpatients' wake-ups was recorded using smart bracelets and mobile terminals. This information was used as an indicator of inpatients' sleep quality to validate the feasibility and effectiveness of the proposed noise control system. For the control group, the monitor did not

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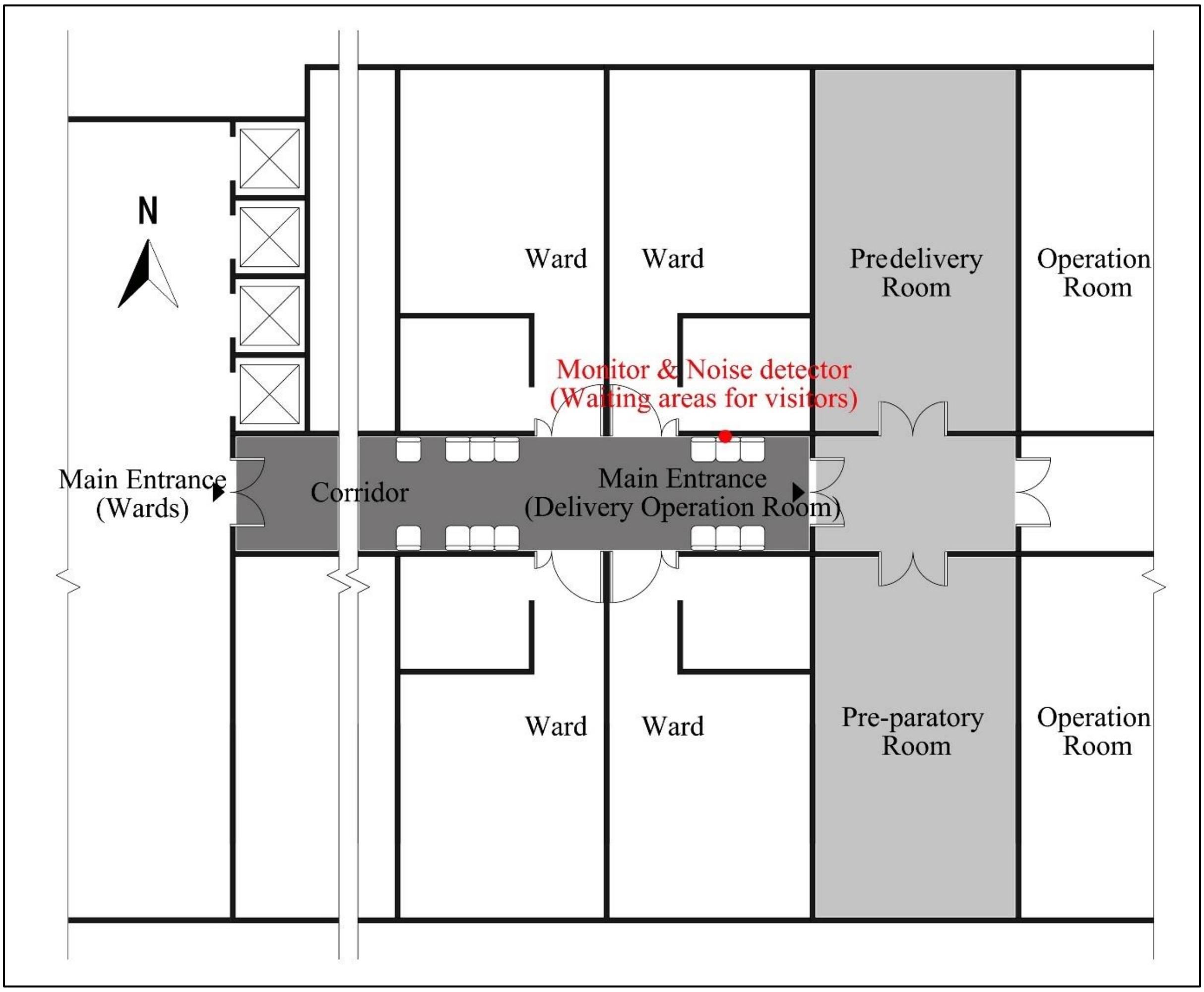
provide reminders at night (08:00 pm–08:00 am), which could be viewed as the variable of this control experiment.

Figure 3

The monitor and noise detector in the waiting areas of maternity wards and operation rooms (Ban et al., 2018).



Another questionnaire survey for both experimental and control groups was conducted to explore inpatients' attitudes about the effectiveness of using the user behavior monitoring system to control the noise in the maternity wards. They were asked to evaluate the satisfaction levels with acoustic environments under the different situations (with and without the noise control system), by using a 5-point Likert-type-scale method (i.e., *not at all satisfied*–1, *slightly*

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satisfied–2, *moderately satisfied*–3, *very satisfied*–4, and *extremely satisfied*–5). In total, 400 questionnaires were randomly distributed during the whole experiment period, 100 copies for each week equally. Finally, 69 usable questionnaires (of 200) were collected from the experimental group (response rate: 34.5%) and 83 (of 200) were from the control group (response rate: 41.5%; Table 2). Independent-samples *t* test and η^2 were applied to calculate the mean values and then explore the significant differences and their effect sizes.

Table 2

Quantity of usable questionnaires.

Category	Week 1	Week 2	Week 3	Week 4	Total	Response rate (%)
Experimental group	31	0	38	0	69	34.5
Control group	0	42	0	41	83	41.5

Step 4: A Follow-up Interview

For the last step, a follow-up in-depth interview was conducted. The recommendations of the experts who were from the fields of healthcare environment design, medical treatments, and hospital administration were used to further optimize the research findings and provide suggestions for the relevant design guidance for healthcare environments in China. Based on snowball sampling methods, in total, 11 experts, including three architects, three doctors, three nurses, and two administrators in hospitals, were invited to discuss the strengths and weaknesses of the design strategies of maternity wards and waiting areas. Each meeting lasted 30 min. Based on the results of all above studies, the selected experts were asked about two questions: “Question 1–Is it necessary to provide enclosed waiting areas to maternity wards and operation rooms for noise control, based on the finding that people tend to reduce unnecessary noise behaviors if they noticed the negative impacts?” and “Question 2–What do

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you think is the appropriate design for the trade-off between therapeutic spaces and waiting areas in maternity wards?"

Data Analysis

All information achieved from the four steps consisted of both qualitative and quantitative data. For the qualitative data achieved from the interviews, the grounded theory was applied to summarize the key words from consultations and recommendations. In terms of quantitative data achieved from 5-point Likert-type-scale methods, sound level meters, and smart bracelets, the program Statistical Product and Service Solutions (Version 21) was applied to calculate the mean values, extreme values, and significant differences.

Results

Major Noise Behaviors in Maternity Wards

According to the consultations in the group interview, the noise behaviors were distinguished from available sounds in the maternity wards, including phone ringing, baby crying, visitor chatting, door/closet closing, nurse inspection, footstep, coughing, tap water dropping, toilet flushing, and snoring. The influence degrees of these behaviors were then evaluated by the participants of the first-round questionnaire survey. The mean values showed that phone ringing (4.97), baby crying (4.84), footstep (4.22), and visitor chatting (4.19) were evaluated at the level of "very influential"; door/closet closing (3.97) and nurse inspection (3.73) were evaluated at the level of "somewhat influential"; while toilet flushing (2.95), tap water dropping (2.81), coughing (2.81), and snoring (2.65) were at the level of "slightly influential." The results of the quantitative study illustrated the order of inpatients' attitudes about the noise behaviors.

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The results of the qualitative study (i.e., the in-depth interview) verified the findings of the quantitative study and further identified the noise behaviors of which this research was concerned. **According to the consultations**, **visitor chatting was the biggest influential noise behavior for the inpatients in the maternity wards since there was a direct conflict between this noise behavior and inpatients' rest and emotions**. The waiting area was designed near the wards and operation rooms for the purpose of medical efficiency, but the visitors there were chatting all days (Figure 3). As the time of delivery operations was not fixed, not all hospitals in China set specific schedules of visiting inpatients for maternity wards. Based on the observations, the service time of waiting areas in the obstetrical department of this hospital was 24/7. Visitors could access these areas all day and night. At night, the family members who were waiting outside for intraoperative patients tried to use chatting to avoid falling asleep during operations. Some of them did not realize that their voice volume had impacted the sleeping quality of some inpatients. Moreover, the participants claimed that phone ringing was a low-frequency noise behavior, as some of owners would put the ringing phones on silent mode after the first ringing. Baby crying and nurse inspection were considered as normal and understandable phenomena, and they could only be solved by the design strategy of single wards. In terms of other noise behaviors, such as footstep, door/closet closing, and toilet flushing, participants indicated that noises could be reduced based on equipment upgrades including high-quality floors, furniture, and sanitary appliances. Since all participants had agreed with the relative influence of those noise behaviors, it was concluded that the results of the first-round questionnaire survey and in-depth interview were basically consistent, and the findings of those influential noise behaviors were credible. Phone ringing, baby crying, footstep, and visitor chatting were identified as the major noise behaviors in maternity wards. The "visitor chatting" was chosen as the research scope. The feasibility of a monitoring system that used patients' behavior information (i.e., sleep rates and quality) for visitors' behavior modification and noise control was then explored through a control experiment and comparative studies.

Performance of The Noise Control System

The statistical results of patients' sleep quality illustrated that the average wake-up frequency of inpatient representatives in the experimental group (with the monitoring system on) was significantly less than that in the control group (without the monitoring system on): 1.67/person night compared to 1.91/person night. The values of the highest noise volume were 71 dBA (experimental group) and 76 dBA (control group) in the waiting area, while those in the wards were 61 dBA (experimental group) and 67 dBA (control group), respectively. These results further verified the finding of observations–the waiting areas were a remarkable location with excessive noise levels in the obstetrical department.

In terms of inpatients' satisfaction with the acoustic environment, it was found that inpatients in the experimental group felt moderately satisfied (with the mean value 3.9420), and the inpatients in the control group had the same feeling (with the mean value 3.0843). Based on the results of Independent-samples *t* test, including the value in the Sig. column (.804) above .05, and the value in the Sig. (2-tailed) column and the Equal variances assumed line (.000) less .05, it showed that there was a clear significant difference on inpatients' satisfaction between the experimental group and control group. The magnitude of this significant difference, calculated according to the effect size statistics η^2, was .151, which meant that there was 15.1% of the variance in the satisfaction of inpatients.

According to the above results, **this user behavior monitoring system (i.e., smart bracelets–mobile terminals–computers–monitors) could effectively reduce the noise**

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levels of visitor chatting, **which to some extent was caused because of the degree of social civility–an impolite behavior of being noisy in public**. Moreover, this phenomenon would be more serious for maternity wards. Based on the observation, it was found that the family members waiting outside of operation rooms were full of joy and worry. These emotions led to that people were more willing to communicate in order to express happiness and release pressure. Therefore, they had to be reminded to moderate their behaviors and maintain an acceptable voice volume for inpatients' well-being. The calculation, including inpatient representatives' wake-up frequency, their satisfaction with the acoustic environment, and the change of the highest volume of noises, showed that such reminders were effective for noise control. Moreover, the reminders could reduce the frequency of high-volume noises by changing users' behaviors, which could lower the frequency of inpatients' wake-ups. However, the effectiveness of this system was limited, as the noise level in the wards (61 dBA) was still above the benchmarking standard (55 dBA) suggested by the WHO. As the highest volume could still exceed the benchmarking standard and the users' satisfaction level was "moderately satisfied," it was necessary to adopt new design strategies (e.g., enclosed waiting areas) to control the noises generated by the intraoperative patients' family members.

Consultations of The Experts from Relevant Fields

The proposed design strategy of enclosed waiting areas was discussed in the follow-up interview. For the first interview question, seven experts of 11 (63.6%), including one architect, two doctor, two nurses, and two administrators, clearly indicated that there should be an enclosed waiting room for the family members of intraoperative patients. While other experts (36.4%), including two architects, one doctor, and one nurse, argued that the enclosed waiting areas were not necessary for maternity wards.

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In terms of the second question, the experts who had voted "necessary" listed two main reasons–enclosed waiting areas could effectively reduce the noise levels of wards and operation rooms and few people would gather around the entrances of operation rooms and thereby would not influence the transportation in the corridor. A nurse said that she had to shout to the crowd out of the way sometimes when she was wheeling a patient into surgery. One of doctors claimed that she could hear the outside sounds from predelivery rooms. She believed that the noise might bring nervousness to some patients who were lying in bed and waiting in the struggle for surgery. According to this doctor, once in the predelivery room, a patient asked this doctor to shut her husband up, as she felt that a continuous, loud, and exciting chatting from her husband outside of the operation room meant he cared less about her. All these experts agreed that this design strategy should be included in the design guidance for healthcare buildings. However, the experts who had voted "unnecessary" indicated that such typical design would compromise therapeutic spaces. The current spatial layout was the best available design to make a balance between therapeutic spaces and waiting areas. The waiting areas of visitors should be designed near the operation rooms. According to the Tort Liability Law in China, when there was an emergency for an intraoperative patient in the operation process, the responsible family member, who was the patient's husband generally, should be informed by medical staff as soon as possible and provide a signature for any further actions (Law Center of Law Press China, 2010). An enclosed waiting room near the entrances of operation rooms, which would not influence medical staff to inform family members, might occupy the floor area of wards and cause a reduction of beds, according to the current situation of general hospitals in China. Such design did not meet the current requirement of Chinese society–the medical resources were limited for some hospitals, especially those in prefecture- and county-level cities. Some other design strategies–for example, soundproof material for doors and walls,

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could be used to achieve the same effect for noise control. The user behavior monitoring systems were also appropriate. Therefore, they argued that the design strategy with enclosed waiting areas could be included in relevant guidance in a voluntary basis, instead of in a mandatory criterion, for all healthcare buildings in China.

Discussion

Enclosed waiting rooms, especially for maternity wards and operation rooms, could gather all visitors together in a sound-insulating space to keep the indoor noise level below 55 dBA. They could also keep the entrances and corridors unblocked and quiet and help medical staff contact relevant family members without delay. It ensured an appropriate balance of relationships between visitors, medical staff, and patients. However, this design strategy might occupy the floor area of wards, as these rooms had to be placed near the entrances of operation rooms.

There were some concerns in the debate of the balance between therapeutic spaces and waiting areas. The first part is visitors' health. A clinical experiment indicated that communication was an important way of relieving the stress of visitors and family members during the waiting process, which should be encouraged (Hui & Tse, 1996). According to the Building Research Establishment Environment Assessment Method Healthcare 2008, it was required that "at least 80% by floor area of public spaces," including reception, retail unit, and waiting areas, should have an adequate "view out"–the waiting rooms "must be within 7 m (22.97 ft) distance of a window or permanent opening" out of "a soft landscaped area" (Building Research Establishment, 2012). The typical design of open waiting areas near the entrances could not meet these requirements. The waiting rooms with windows were also helpful to the natural ventilation and indoor air quality, which could prevent the cross infection

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of diseases in the crowd. Moreover, a good environment could reduce the negative emotions of visitors during waiting, and it might improve the doctor-patient relationship. This could be considered as the second part of concerns–the safety of medical staff. These potential behaviors of visitors should also be included in the consideration of healthcare environment design. According to some experts in the follow-up interview, some general hospitals in the metropolises of China, especial for private facilities, have considered an enclosed waiting room as a necessary design solution for obstetrical departments that can improve the quality of healthcare environment management. Furthermore, some hospitals implemented administrative measures, for example, stablishing visiting hours and limiting visitor quantity in order to keep a comfortable indoor environment for maternity wards. But according to the observations in this research, these measures would not be effective, when the waiting areas were designed as open and public spaces in corridors. Enclosed waiting rooms could optimize administrative management of hospitals.

Currently, in some areas where medical resources are relatively sufficient, single family rooms, which are called labor–delivery–recovery–postpartum rooms because of the integrated functions, have been used to further improve the indoor environments of maternity wards. Such design strategy can reduce almost influential noise behaviors. It can also gather all family members together by making waiting areas break up the whole into parts. Patients, babies, and visitors can be in a harmonious state based on the balance of connection and isolation in spaces.

In addition, the wake-up frequency, which was utilized as an indicator of evaluating inpatients' sleep quality and the feasibility of the noise control system in this research, was calculated from smart bracelets and mobile terminals manually (Figure 4). It was important to note that the algorithms of people's sleep quality in the smart bracelets had some disadvantages on sensitivity. During the early tests, it was found that the smart bracelets did not define the

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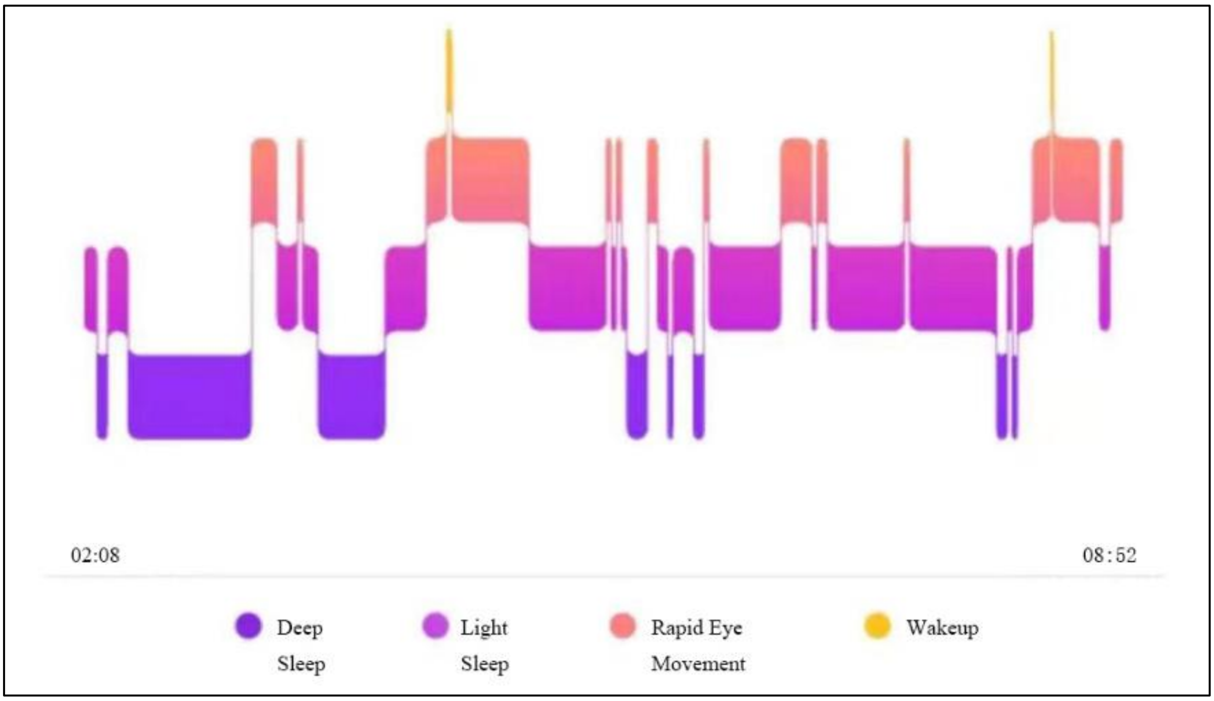
quick wake-up (i.e., waking up suddenly, turning over, and falling asleep immediately) as a "wake-up." This situation might affect the calculation results, but it could still validate the effectiveness of this user behavior monitoring system. Professional medical instruments and complete network systems should thereby be utilized to further test the sleep quality of inpatients, which could improve the data accuracy and research outcomes.

Figure 4

Example of wake-up frequency calculated by smart bracelets and mobile terminals.



Conclusions

It is found from this research that the inpatients of maternity wards are easy to be exposed to excessive noises during the hospitalization. It deserves more attention in the process of design and construction through equipment upgrades and functional optimization. This research identified the major user behavior patterns of noise sources in the maternity wards of a general hospital–visitor chatting was considered as the most influential noise behavior. Some

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design strategies were discussed to reduce these noises generated by visitor behaviors in maternity wards. Based on the information summarized from all investigations and experiments, it is found that, **for the current situation in China**, **the best design strategy of waiting areas is to build a separate and enclosed space. This can reduce the noise levels of maternity wards and operation rooms**, **keep corridors and entrances unblocked**, **and ensure the efficiency of medical treatments**. Moreover, all finding of this research validated the suggestion that user behavior information should be included in healthcare environment design as a type of building information for the satisfaction of users with healthcare environments.

In the future work, more on-site measurements and field investigations will be conducted to provide test-retest studies in order to optimize some issues (e.g., response rates and bracelets' sleep calculation methods) and ensure the reliability of relevant findings. The interactions between user behaviors and indoor equipment (e.g., alarms and heating, ventilating, and air-conditioning systems) will be discussed to develop more interventions that can be implemented for the noise control of maternity wards. Professional medical instruments will be applied to improve the accuracy of information collection in order to gain an insight into patients' sleep quality and the influence for their health.

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