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The Neonatal Intensive Care Unit (NICU) Context and the Perceived Soundscape: A Grounded Theory Approach

Cemre Orhan, MFA[1], and Semiha Yilmazer, PhD[1]

Abstract

Background: Studies address excessive sound levels and their adverse effects on infants in neonatal intensive care units (NICUs). However, objective measurements represent merely one aspect of the acoustic environment, and investigations into staff's perceptions of the acoustic environment remain scarce in the NICU context. A holistic approach, soundscape, is needed to explore the acoustic environment in-depth. **Aim:** This study aims to (1) contribute to indoor soundscape literature and inform decision-makers of future NICU design and research by focusing on staff members' perceptions of the soundscape and (2) explore whether there is a relationship between staff members' perceptions of soundscapes and the built and acoustic environments of one NICU. **Methods:** Following the ISO/TS 12913-2/3 protocols, semi-structured interviews were conducted with 10 NICU staff members and analyzed using the grounded theory to generate a conceptual framework for NICU soundscapes. **Results:** The results indicated that the task-related sounds, including false alarms, were neutrally responded to as they evoked acceptance and adaptation behaviors. The sound sources perceived as irrelevant were responded to negatively. NICU staff indicated that although they expect to hear alarms clearly, specific features of alarms caused several physiological and psychological problems. **Conclusions:** The findings of the study revealed the importance of conducting a soundscape approach to investigate NICU acoustic environment in detail. The study showed that staff members' perceptions and responses primarily depend on the context rather than on sound levels.

Keywords

indoor soundscape, neonatal intensive care unit, built environment, acoustic environment, perception, context, grounded theory

Introduction

The acoustic environment of a place is the whole of sounds from all sources that could be heard by an individual in that place (Brown et al., 2016). A person's perceptual construct of the acoustic environment is known as the soundscape of a place (Brown et al., 2016; Kang, 2006). The soundscape evokes responses and outcomes that

[1]Department of Interior Architecture and Environmental Design, Faculty of Art, Design and Architecture, I.D. Bilkent University, Ankara, Turkey

Corresponding Author:
Cemre Orhan, MFA, Kalkınma Mahallesi, 113 Nolu Sokak, No: 19/11, Ortahisar, Trabzon 61080, Turkey.
Email: cemre.orhan@bilkent.edu.tr

can be attributed to the specific context in which the sound is heard (Brown et al., 2016; Orhan & Yilmazer, 2021). In an environment, context refers to all nonacoustic components of the place and extensively impacts individuals' perception of soundscapes (Brown et al., 2016).

Soundscape interferences are still evolving in healthcare environments, including patient waiting areas (Uğurlu & Yilmazer, 2022; Watts et al., 2016), nursing homes (Aletta et al., 2018), hospital wards (Mackrill et al., 2013), and intensive care units (ICUs; Okcu et al., 2011). ICUs are considered the most critical environments among these facilities as they provide vital care to seriously ill patients through highly skilled staff (Clancy & Johnson, 2021; Tronstad et al., 2021). Failing to address supportive work environment conditions can harm staff performance, well-being, and patient care (Obeidat et al., 2022).

Many ICU acoustics studies focus only on the measurements of physical parameters (Casey et al., 2020; Garcia Guerra et al., 2018; Hernandez-Molina., et al., 2020; Kramer et al., 2016; Naef et al., 2023; Park et al., 2014; Ramm et al., 2017; Song et al., 2022). Objective measurements of sound levels represent merely one aspect of the acoustic environment. To be able to explore individuals' perceptual approaches toward soundscapes, it is essential to understand the effect of the context on individuals' perceptions (Orhan & Yilmazer, 2021). Although studies explored the subjective responses of ICU users toward the acoustic environment to a certain degree (Cho et al., 2016; Hasegawa et al., 2020; Kebapcı & Güner, 2021; Movahedi et al., 2023; Okcu et al., 2011; Sowan et al., 2015), no exploratory studies have applied the soundscape approach following the ISO/TS 12913-2/3 protocols with the focus of the context. This study aims to investigate staff members' perceptions and subjective responses to a neonatal ICU (NICU) acoustic environment using a soundscape approach.

The Acoustic Environment of ICUs

ICUs are the hospitals' essential acute services that provide vital care to seriously ill patients through highly skilled staff (Clancy & Johnson, 2021; Tronstad et al., 2021). Nightingale (1859) emphasized the impact of the healthcare environment on its users' health and well-being. However, these facilities are full of stressors that negatively impact the users' experiences and perceptions of their physical environments (Sundberg et al., 2017).

Noise is one of those main stressors that affect the quality of user experience in healthcare facilities (Ulrich et al., 2008). The sound levels have progressively increased in hospitals, particularly in the ICUs, since the 1960s (Busch-Vishniac et al., 2005) and exceeded the levels than those recommended by scientific organizations (Dawson et al., 2022). Increases in sound levels and constant exposure to them are found to be associated with significant increases in subjective measures of stress in ICU staff (Kebapcı & Güner, 2021; Kooshanfar et al., 2022). Moreover, noisy ICU work environments are contributing factors to nurses' performance obstacles (Kooshanfar et al., 2022), medical errors, and patient safety problems (Kebapcı & Güner, 2021; Santos et al., 2018).

The NICU specializes in caring for ill or premature neonates (Shepley, 2014). A growing body of literature addresses excessive sound levels (Hernandez-Molina., et al., 2020; Khowaja et al., 2022; Mayhew et al., 2022; Ramm et al., 2017; Vicencio et al., 2023), their adverse effects on infants (Beken et al., 2021; Cardoso et al., 2015; Gholami et al., 2023; Restin et al., 2021), and staff members' perspectives on the acoustic environment of NICUs (Chawla et al., 2017; Darcy et al., 2008; Sabetsarvestani et al., 2022; Santos et al., 2018; Spagnol et al., 2022). However, investigations into staff's perceptions of the acoustic environment using the soundscape approach remain scarce in the NICU context.

The Soundscape Approach

The soundscape is a holistic approach that refers to the perceptual construct of the acoustic environment (Schulte-Fortkamp et al., 2023). The International Organization for Standardization (ISO) introduced three standards to guide soundscape studies. The first standard, ISO 12913-1, published the soundscape's definition and

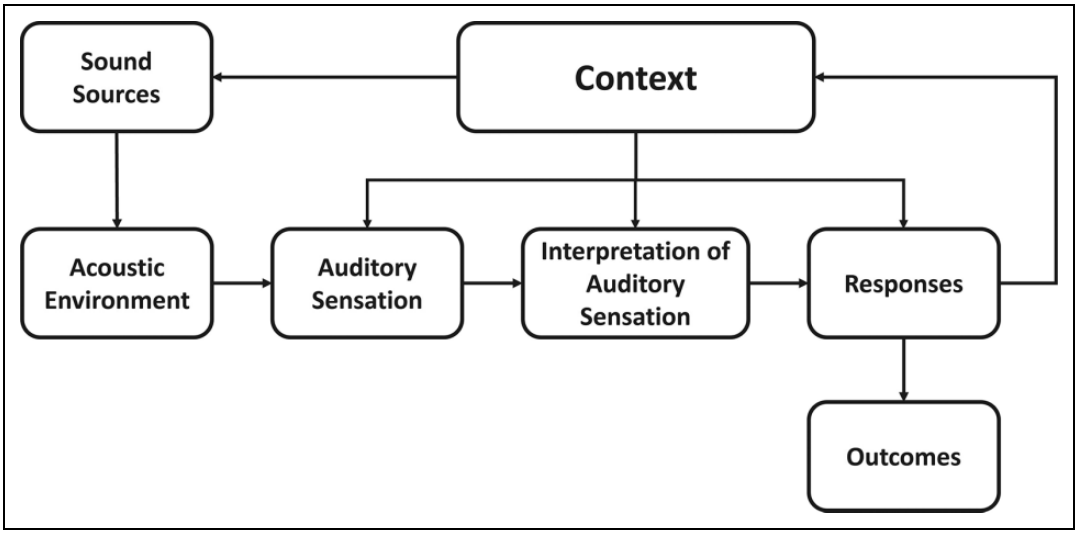

Figure 1. The conceptual framework of soundscapes consists of concepts such as context, sound sources, acoustic environment, auditory sensation, interpretation of the auditory sensation, responses, and outcomes. *Source*: ISO (2014).

conceptual framework (Figure 1) as "the acoustic environment perceived or experienced and/or understood by a person or people, in context" (ISO, 2014). Context refers to "the interrelationships between person, activity, and place, in space and time, and it may influence soundscape through the auditory sensation" (ISO, 2014; Schulte-Fortkamp et al., 2023). The second standard, ISO/TS 12913-2, revealed the Data Collecting and Reporting Requirements for soundscape studies (ISO, 2018). The standard elaborates on soundscape methods: Method A (questionnaire), Method B (soundwalk), and Method C (interview) with sample data collection tools. Lastly, ISO/TS 12913-3 published a Data Analysis standard that extensively specifies the processes one would use to analyze the data collected through stated methods (ISO, 2019).

Although most soundscape studies have focused on urban soundscapes for decades, many recent attempts have been made to explore indoor soundscapes of buildings, where people spend most of their time and are most affected by the acoustic environment (Torresin, Albatici, et al., 2020). The indoor soundscape research aims to characterize the "indoor acoustic environment as perceived or experienced and/or understood by a person or people, in the context defined by the building" for designing spaces that support human activities and improve people's well-being (Torresin et al., 2022). In their investigation of how the built environment can support task performance and enhance health-related outcomes and well-being, researchers demonstrated that interviews can be used as an effective tool to gather detailed data and to measure perceived indoor soundscapes (Torresin, Aletta, et al., 2020).

Interviews are common assessment methods to examine the acoustic environment (Engel et al., 2018) and to provide valid detailed soundscape data (Kang & Schulte-Fortkamp, 2018). Qualitative interview data are frequently analyzed with grounded theory (GT) which is becoming an expanding method in soundscape studies (Acun & Yilmazer, 2018; Çankaya Topak & Yilmazer, 2022; Orhan & Yilmazer, 2021). GT aims to build theory inductively among the gathered data (Voith et al., 2023) and allows one to discover similarities and differences in subjective responses given to the same phenomenon (Actis Danna et al., 2023). GT uses three stages of an iterative coding process that increases the generalizability of the outcomes, including open, axial,

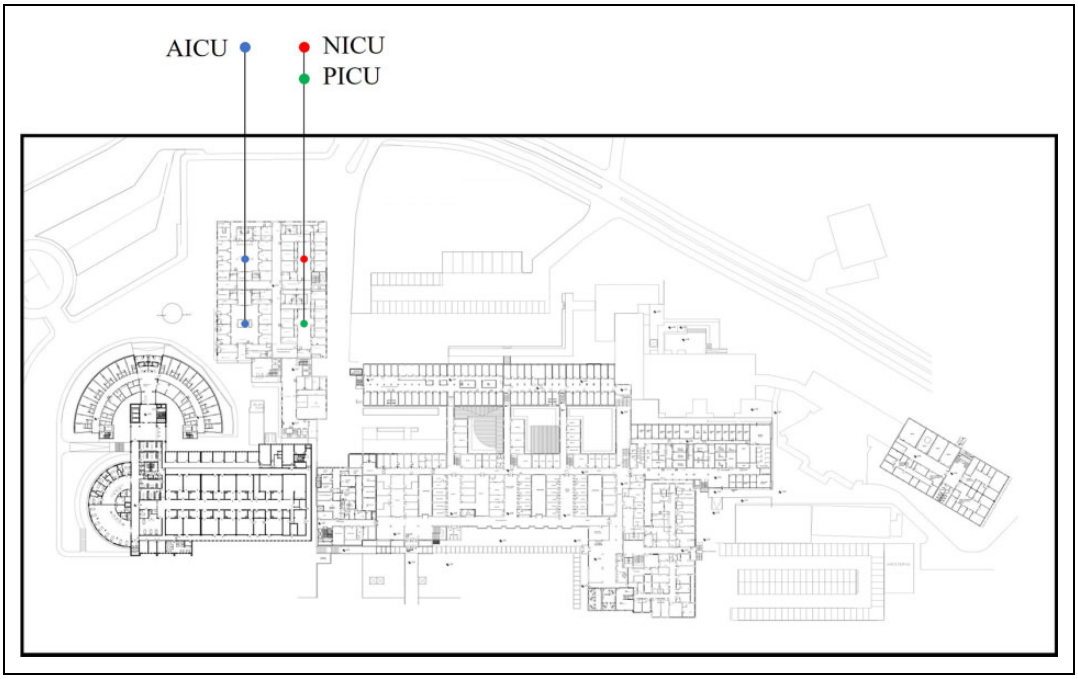

Figure 2. The location of the hospital and the neonatal intensive care unit.

and selective coding, with each stage more structured than the previous one (Orhan & Yilmazer, 2021).

This study aims to contribute to indoor soundscape literature and inform decision-makers of future NICU design and research by focusing on staff members' perceptions of the soundscape. Studies have shown that the context of soundscapes is connected to and affected by the built and acoustic environments (Acun et al., 2018; Acun & Yilmazer, 2018; Çankaya Topak & Yilmazer, 2022; Orhan & Yilmazer, 2021; Yilmazer & Acun, 2018). Based on these connections, this study presents an approach that analyses the relationship between staff members' perceptions of soundscapes and the built and acoustic environments of one NICU. The study aims to explore staff members' perception of built and acoustic environments in a NICU and create a conceptual framework using the GT approach.

The research questions were generated as follows: How do the built and acoustic environments affect the perceived soundscape of NICU? How does the context affect staff members' perceptions and responses toward the soundscape of the NICU? In that manner, we conducted semi-structured interviews with NICU staff, analyzed the data with GT, and generated a conceptual framework for NICU soundscapes.

Method

Site

This study was conducted at the university hospital in Trabzon, Turkey. The hospital building is located in the city center and close to the university campus, the city airport, and the industrial zone. The studied NICU is located on the second floor of the hospital wing with other ICUs (Figure 2). In 2021, the NICU moved from an open-plan model unit to a single-room unit because of architectural renovation. This place was designed and used for an adult ICU before the NICU was moved temporarily.

The nursing station is at the end of the main hall. The supportive subspaces are the nurses' room, kitchen, on-call room, storage, interns' room, utility room, information room, and treatment preparation room (Figure 3). Six patient rooms include two

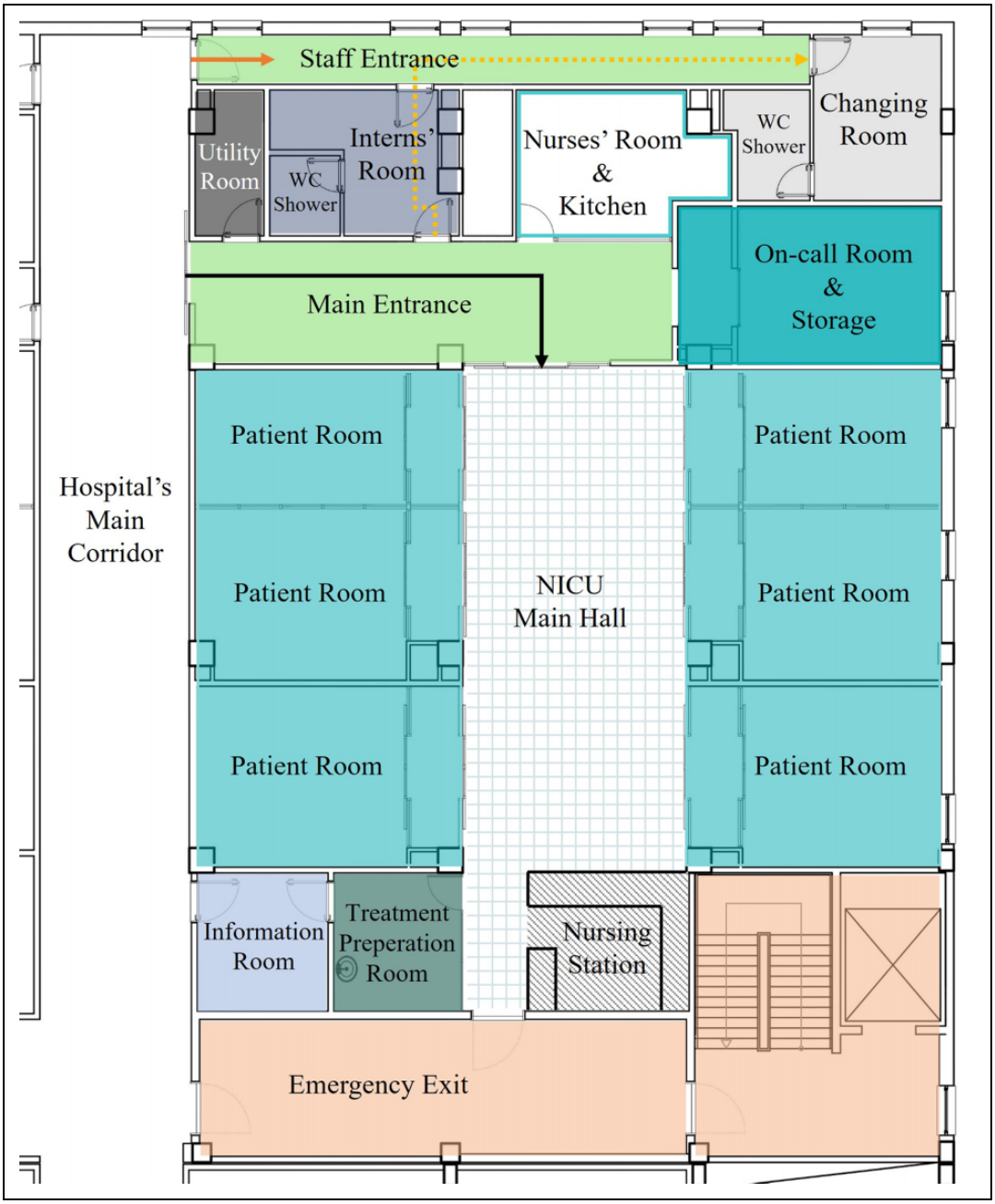

Figure 3. The plan layout of neonatal intensive care unit.

or three incubators with glass sliding doors. There are three different shift times, 8, 12, and 16 hr, and four nurses cover the day and night shifts with a patient ratio of 1:3. ISO/TS 12913-2 suggests classifying the sound sources under "sounds of technology," "sounds of nature," and "sounds of human beings" categories to report the existing acoustic environment (ISO, 2018). Table 1 shows the sound sources observed by researchers in the NICU setting during the study.

Table 1. Sound Sources in Neonatal Intensive Care Unit (NICU).

Categories	NICU
Sounds of technology	Alarms, telephone, doorbell, sliding doors, trolleys, rattle (pencils, papers, trash bin, falling things, and medical stuff), and rustle (galosh, trash bags, and medical stuff)
Sounds of nature	Water (handwashing)
Sounds of human beings	Staff conversations, crying babies, shouting, coughing, sneezing, laughter, and footsteps

Table 2. A Table Showing the Neonatal Intensive Care Unit Staff's Demographic Information.

Demographics		Frequency (*N*)	Percentage (%)
Gender	Female	10	100.0
Age range	25–34	3	30.0
	35–44	7	70.0
Occupation	Nurse	8	80.0
	Doctor	1	10.0
	Caregiver	1	10.0
Experience	Fewer than 10 years	4	40.0
	10–14 years	3	30.0
	15–20 years	3	30.0

Participants

Twenty-five nurses, three assistant nurses, three doctors, and nine personnel ($n = 40$) work in the studied NICU. Among these staff members, three nurses were responsible for general duties (e.g., education, training, screenings) and five personnel were responsible for supporting duties (e.g., unit cleaning, laundry, carrying medical devices). All nurses, personnel, and doctors who provided patient care and wanted to voluntarily participate in the study were interviewed. We excluded staff members who did not provide direct patient care ($n = 8$) and in-training professionals, such as assistant nurses ($n = 3$). Among the eligible staff members ($n = 29$), a convenience sample of 10 NICU staff (eight nurses, one doctor, and one caregiver), all female (M age = 35.4 years, SD age = 6.04 years, and age range 25–41) and experienced (M experience = 9.08 years, SD age = 6.26 years, and experience range 0.3–17 years) participated voluntarily in the interview (Table 2). Participation stopped when the gathered data reached theoretical saturation (Strauss & Corbin, 1998).

Data Collection and Analysis

Detailed guidelines must be considered to guarantee compatible data collection in soundscape studies (ISO, 2018). ISO standards provide a guideline interview sample to perform and analyze Method C (ISO, 2018, 2019). Fifteen questions were formed regarding built and acoustic environments to understand participants' perceptions of ICU soundscapes (Table 3). We also asked spontaneous questions based on the conversation. The interview was conducted in Turkish and audio recorded. The data collection process stopped when the data reached theoretical saturation (Strauss & Corbin, 1998). The audio files were transcribed verbatim and coded in Turkish.

The GT approach has three coding steps: open, axial, and selective coding. Once all recordings were transcribed, the initial data were broken down into key phrases to identify the related and unrelated items. To illustrate, the statement "Monitor sounds" was coded as "sounds of technology"; "annoying" was coded as "feeling annoyed"; and "very high-pitched and rhythmic" was coded as "sound characteristics." Moreover, "warn us as stimulus," also referred to "being stimulated," and "we take action automatically" were coded as "taking action." The phrase continues with the sentence "It is vital to hear those sounds . . . disturbing but must be heard" was coded as "important/informative sound content," "context-related sounds," and "need to hear

Table 3. The 15 Main Questions of the Semi-Structured Interviews.

The Built Environment
1. What do you expect NICUs to have in the built environment? (Orhan & Yilmazer, 2021)
2. How satisfied are you with working in this environment? Why? (ISO, 2018)
3. How do you feel about the physical environment in this ICU? (ISO, 2018; Orhan & Yilmazer, 2021)
4. Where do you spend most of your time in this place? Why? (ISO, 2018)
5. In which subspace do you usually prefer to spend your time? Why? (ISO, 2018)
The Acoustic Environment
6. What do you expect to hear in NICUs? (Orhan & Yilmazer, 2021)
7. What kind of sounds do you hear in this place and how do they make you feel? (ISO, 2018; Orhan & Yilmazer, 2021)
8. What kind of sounds you hear are pleasing/disturbing? Why? (ISO, 2018; Orhan & Yilmazer, 2021)
9. Is there any time that you can control or must exposed to the specific sound sources? (ISO, 2018)
10. How important is sound in this context? (ISO, 2018)
11. Is there a sound that helps you to identify certain events? (ISO, 2018)
12. Do you think sounds cause tension and disagreements between you and other staffs in this environment? (ISO, 2018)
13. Do you think the sound you are exposed to causes a health problem? (ISO, 2018)
14. What do you do to avoid unwanted sounds? (ISO, 2018)
15. What should be done to improve the sound environment in this environment? (ISO, 2018)

alarm" (Figure 4). The interview data were analyzed to find the repeated statements and key phrases that were accredited to them. After the key phrases were conceptualized, they were grouped back to generate the categories, and their relations were explored. Lastly, the systematic categorization of NICU soundscapes was generated.

Ethical Considerations

The study was approved by I.D. Bilkent University Ethics Committee (2022_07_22_03). We informed each participant about the study and their right to withdraw at any step without giving any reasons via written consent. Participants' confidentiality and anonymity were protected, and all data were stored and used as legislation required.

Results

Interview data were analyzed with the coding process as explained and illustrated previously (Çankaya Topak & Yilmazer, 2022; Strauss & Corbin, 1998; Figure 4). First, we sorted memos and created key phrases during the initial data collection and analyses. Then, we labeled the key phrases in open coding and conceptualized the data in axial coding. To illustrate, in the labeling process, *sounds of technology, context-related sounds,* and the *need to hear alarm* key phrases were coded as "a1," "a3," and "a4" to improve the study with an order. Later, these concepts were conceptualized based on their similarities as "aa5," which shows "staff members" expectations of hearing alarms in NICU context. These codes were categorized considering their similarities. For instance, "aa3," "aa5," and "aa6" were gathered, and the A4 was defined, which represents "context determines users" expectations, perceptions, and experiences. A1, A2, A3, A4, and A5 were also categories that included labels about the *context*; these categories were found similar and created the category AA3 as "context." The coding steps were repeated for each statement in the interview. After identifying the core categories and subcategories, we explored their relationship. We selected the main category during the selective coding. The categories were placed in graphical order, depending on the relations between them (Orhan & Yilmazer, 2021). The links and patterns within these relations helped

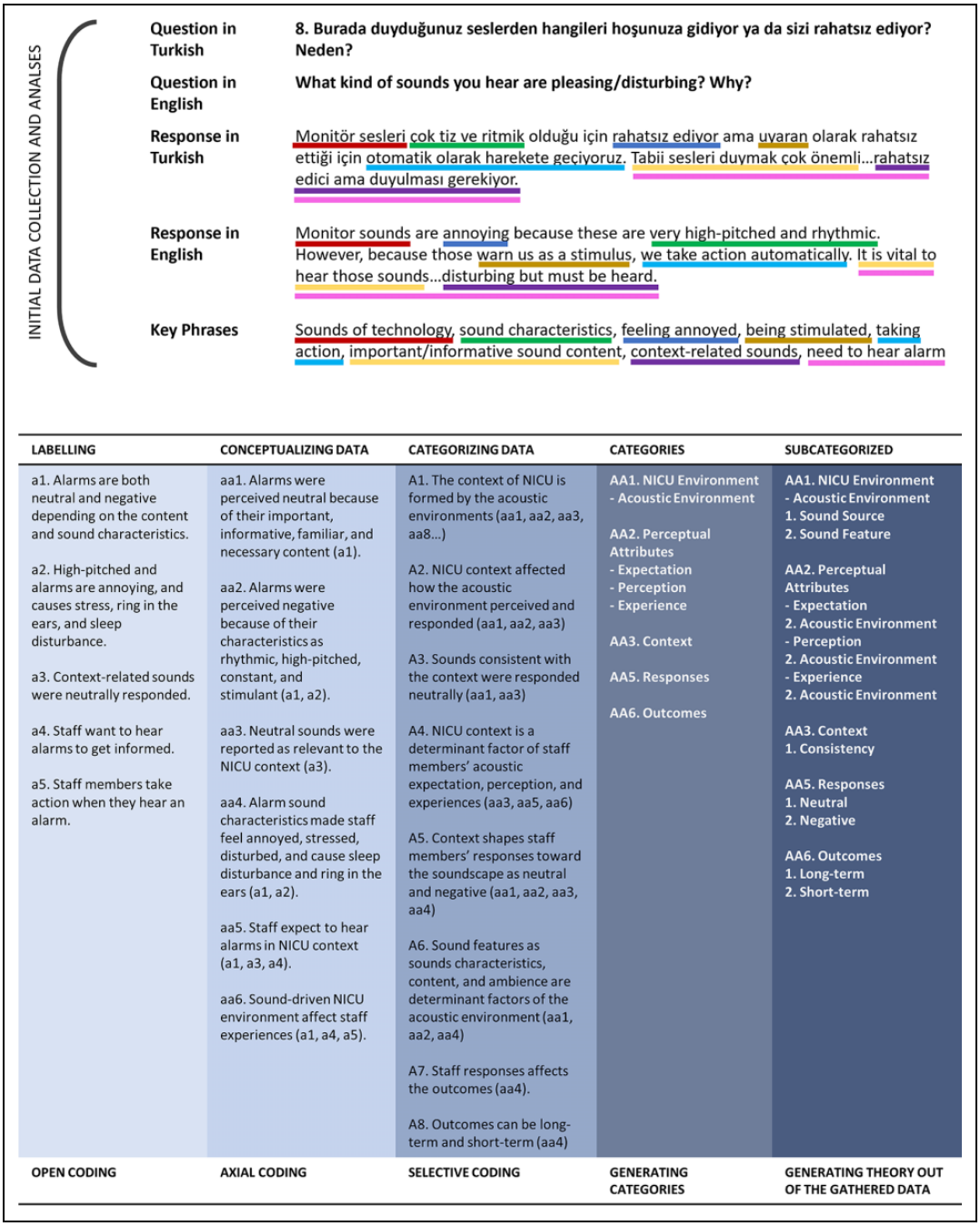

Figure 4. Representation of the coding process with one sample interview statement. *Note*. The data collection and analyses process completed in Turkish and translated in English to illustrate.

to create the conceptual framework, which identifies the staff members' perceptions of soundscapes in NICU (Figure 5).

The interpretation of the soundscape of the NICU was determined based on the categories generated from the gathered data. The analysis

shows that the built environment category influences the acoustic environment category. The NICU environment category directly forms the staff members' expectations, perceptions, experiences, and coping behaviors. A more complicated category follows these categories, the context of the soundscape. Context, the interrelationships between person, activity, and place, is the main category that relates to all categories of this framework. It has been clarified that people, activity, and place are determinant factors of the context of soundscapes (Orhan & Yilmazer, 2021). This framework also indicates that the categories of built and acoustic environments directly influence the context. The category of context affects staff members' coping behaviors and responses toward soundscapes as either neutral or negative; those responses led staff members to come up with long-term or short-term outcomes.

The conceptual framework revealed six categories and 19 subcategories from the GT analysis: NICU environment, perceptual attributes, coping behavior, context, responses, and outcomes (Figure 5). Context was selected as a core category related to all other categories. The categories, subcategories, and related key phrases were indicated in the framework. Each category of the framework was supported with NICU staff members' statements.

NICU Environment

The *Built Environment* and *Acoustic Environment* were created under the category NICU environment. We found that the built environment, *Architectural Factors*, affect the acoustic environment, make staff develop coping strategies, and alter the context in which the soundscape is generated. These factors include subspaces, unit configuration, building systems, and interior design. For instance, NICU staff indicated they have been experiencing poor auditory access in some subspaces because of the unit configuration.

The Acoustic Environment category comprises the *Sound Source*, *Sound Feature*, *Effect*, *Depicter*, and *Intuitive* subcategories. Participants mostly mentioned the technology-based and human-based sound sources, their characteristics, content, and physiological and psychological effects. They also emphasized the specific times and events that these sounds represent. Based on these factors, staff defined the acoustic environment ambiance they expect, perceive, and experience.

Perceptual Attributes—Expected, Perceived, and Experienced NICU Environments

This study showed that the existing NICU environment and context directly affect staff members' expectations, perceptions, and experiences. Since the degree of nursing neediness is higher in neonates than adults, NICU staff expected to see and hear the patients from any point in the built environment. They expected the built environment to provide them with auditory access with a central plan layout and required proximity to enhance communication and delivery of care. The location of the nursing station is off-center, and the incubators were placed in single rooms. Although staff could react to patients' emergencies efficiently and quickly from the nursing station, they have difficulty hearing each other in the patient rooms. They also indicated that it is hard to hear babies, alarms, and colleagues from the nurses' room because of its location. Therefore, they preferred to spend most of their time at the nursing station.

> We are always at the desk, and we come there (the nursing room) momentarily, but since we cannot see the children from there, we have to be at the desk. (Participant 2)

> We have trouble hearing each other when in the patient rooms. (Participant 3)

The acoustic environment of the NICU can be described as eventful, with several different sound sources. Alarms are the most determinant factor of the workflow in the unit. Staff perceived the alarm sound characteristics as rhythmic, high-pitched, constant, and stimulant but expected them to be in a way that is softer, deeper, non-rhythmic, and noncontinuous. They expected to hear important, informative, familiar, and necessary sounds to get informed about patients' status. Moreover, the clarity of these sounds was vital for

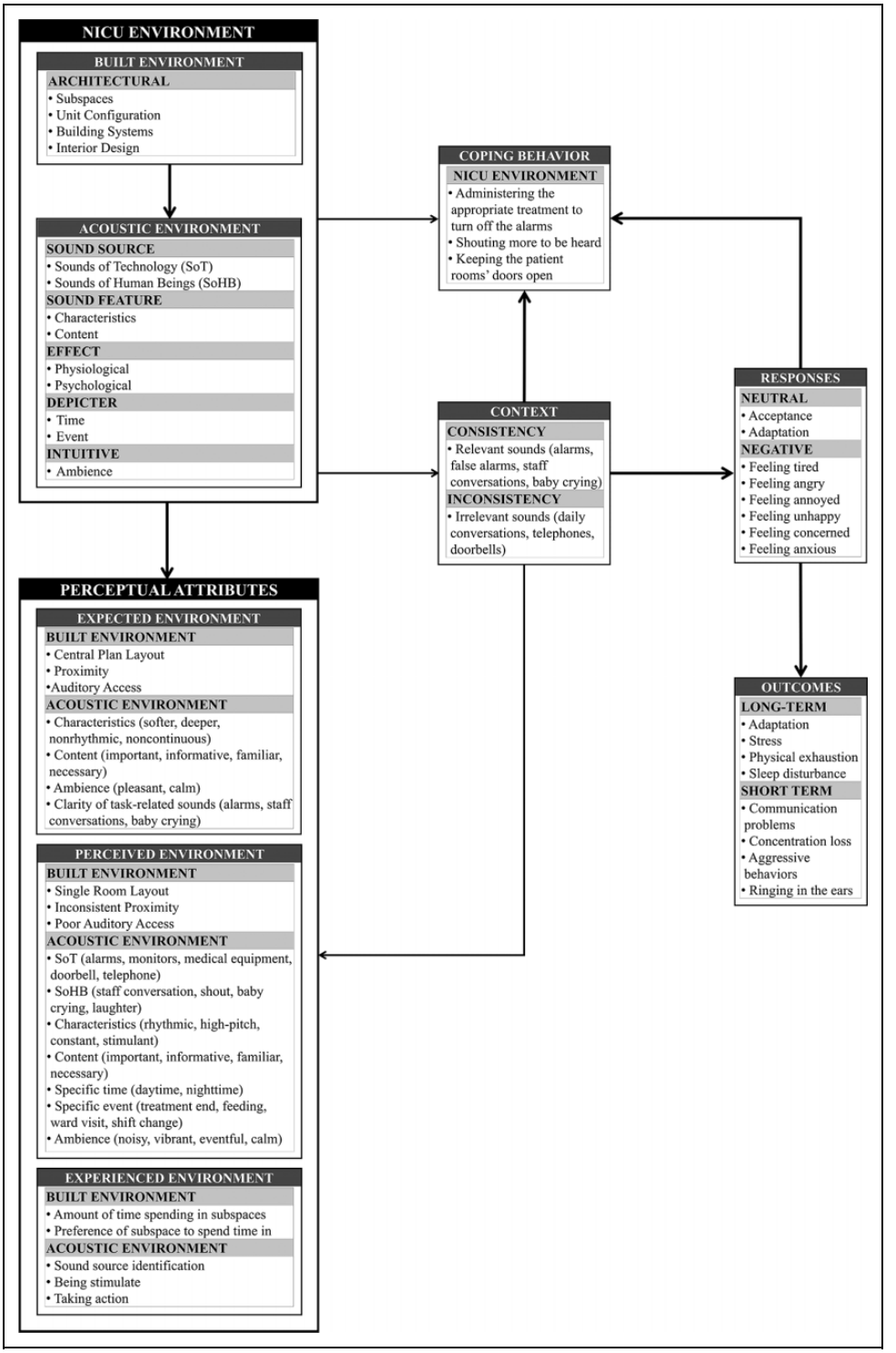

Figure 5. Conceptual framework created out of the gathered data for the neonatal intensive care unit.

sound source identification, being stimulated, and taking action on time.

> Alarms are important and give us information when the patient's condition reaches critical levels . . . we need to hear them. (Participant 7)

> Maybe, softer sounds can be integrated into the monitors. More deep sounds, not raspy sounds . . . . (Participant 1)

The technology-based sounds such as alarms, monitors, medical equipment, doorbell, and telephones were the most frequently mentioned. In addition, human-based sounds such as staff conversations, shouting, baby crying, and laughter were also mentioned in the scope of the perceived acoustic environment. Based on the perceived sound sources, staff members differentiated specific times (e.g., daytime or nighttime) and events (e.g., treatment endings, feeding, ward visit, and shift change). Even though they expected the overall acoustic environment ambiance to be pleasant and calming, they perceived it as noisy, vibrant, and eventful in the daytime, and calm in the nighttime.

Context

The context was found as the main category as it is linked directly to other framework categories. NICU staff responded neutrally or negatively to the soundscape depending on the consistency between the context, the built environment, and the acoustic environment. Staff found the task-related sounds (e.g., alarms, false alarms, staff conversations about patients, baby crying) relevant and consistent with the NICU context. In soundscape studies, context affects individuals' perceptions of the acoustic environment more than the sound levels (Orhan & Yilmazer, 2021). Even though it causes a noisier environment, staff expected to hear alarms, staff conversations about patients during the ward visits, and baby crying to figure out the problem. They perceived these sounds as part of their job. Even the most unwanted sounds could be acceptable depending on their relationship with the context. The staff's acceptance of sounds can be explained by the interpretations of false alarms. Staff perceived the false alarms as a natural outcome of the movements of neonates and accepted them as part of their work environment. On the other hand, NICU staff did not want to hear irrelevant sounds (e.g., daily staff conversations, telephones, doorbells). In that sense, they were dissatisfied with the telephones and doorbells because irrelevant sounds distracted their attention. They also found daily staff conversations inconsistent with the NICU context.

Even the most unwanted sounds could be acceptable depending on their relationship with the context.

> Alarms are a warning for us, after all, they are something important for the patient. There must be alarms. Well . . . yes, alarms are annoying, after all, why would I want to hear that sound all the time? I would like to be in a quiet environment. But this is how intensive care works, exactly as it should be. (Participant 7)

> When babies cry, the alarms go off . . . when they change position, they go off . . . when babies move, they go off . . . but this is neonatal intensive care unit; eventually, it happens . . . . (Participant 9)

> There is no need to hear the nurses' conversations at all. Anyway, those conversations are not things that need to be conveyed to me, those are everyday conversations. (Participant 7)

Coping Behavior

NICU environment, context, and responses formed the coping behaviors of staff. The single-room layout with an off-centered nursing station caused communication problems between staff and poor auditory access. Therefore, the staff solved these issues by shouting more and keeping the patient rooms' doors open. Another problem was the constant exposure to the high-pitched and rhythmic characteristics of alarms. To solve that, staff administer the appropriate treatment to the patients to bring the alarms under control. They do not turn the alarms off or lower the volume for safety reasons unless the alarms are false or unnecessary.

> When we cannot hear each other, we shout more. In a way, we make ourselves heard. (Participant 10)

Responses and Outcomes

Staff members' interpretations of the NICU context formed the category of responses. Staff responses were grouped as *neutral* and *negative*. NICU staff responded neutrally to relevant sounds because of the content of the relative sounds; therefore, the staff accepted and adapted to these sounds from the nature of the work environment. The staff responded negatively to irrelevant sounds and sound characteristics since they made staff feel tired, depressed, angry, annoyed, unhappy, concerned, and anxious. Based on the responses, outcomes are divided into *long-term* and *short-term* outcomes. Long-term outcomes are stress, adaptation, physical exhaustion, and sleep disturbance. Short-term outcomes are communication problems, aggressive behaviors, and ringing in the ears.

> We accepted these sounds. I mean, technology has advanced a lot now, for example, some technological devices can be silent like washing machines, but there is no such thing as making the monitor sounds silent. (Participant 2)

> Everyone has seen the mechanical ventilator sound in their dreams. We have a constant noise issue. If there is a sound, there is a problem. So, this makes us nervous, like, "why is it alarming, did something happen to someone?" This situation also in our dreams, let me say it is not a dream but a nightmare. (Participant 5)

Discussion

Hamilton and Shepley (2010) remark on the need for GT to investigate new problems or gain a fresh perspective on the existing problems in healthcare research. This soundscape study used a qualitative method via the GT approach to generate a conceptual framework for NICU soundscapes. There are similarities between the categories of previously generated conceptual frameworks (Acun & Yilmazer, 2018; Çankaya Topak & Yilmazer, 2022; ISO, 2014; Orhan & Yilmazer, 2021). The context was selected as the main category that directly influenced NICU staff's perceptual attributes, coping behaviors, and responses, forming the outcomes of the NICU soundscapes.

A facility design that supports critical care's crucial work must serve users' needs (Hamilton & Shepley, 2010). We found that NICU staff expect the built and acoustic environments to provide them with proper auditory access. Studies investigating the effects of the built environment on acoustic outcomes have mainly considered the objective measurements of acoustic environment (Carvalhais et al., 2021; Chawla et al., 2017; Darcy et al., 2008; Krueger et al., 2007; Santos et al., 2018). In two classic articles, researchers found that circular plan layouts had noise levels equivalent to rectangular plan layouts (Shepley & Davies, 2003), and closer proximity to the nursing station caused higher sound levels in the closest patient room (Moore et al., 1998). Instead of focusing on the sound levels, NICU staff stated they expect to have auditory access from each subspace. Open, wall-less, and column-less central areas that contribute to auditory access for patient monitoring were found to be expected by staff (Zamani, 2018). Similarly, having nurses' rooms away from the center and the single-room layout caused poor auditory access and made NICU staff concerned and anxious about patient monitoring. Although studies have suggested that the single-room plan layout promotes quieter environments with lower noise levels compared to the open-plan layout (Chawla et al., 2017; Santos et al., 2018), staff members expected the unit to have an open-plan layout to easily hear and see neonates and each other. Therefore, despite the respite needs of staff, they preferred to spend less time in nurses' rooms to ease patient monitoring.

Instead of focusing on the sound levels, NICU staff stated they expect to have auditory access from each subspace.

Proper communication among ICU staff is vital for quality healthcare delivery (Digby et al., 2023). Studies investigated the impact of unit design on communication in healthcare settings (Brewer et al., 2018; Liu et al., 2014; Real et al., 2017; Xuan et al., 2020; Zamani, 2018) and with increased communication, staff experience less stress (Vahedian-Azimi et al., 2019). As proposed by Zamani (2018) and Doede et al. (2017),

the evidence we found shows that the lack of visibility between patient rooms created a communication barrier. Eliminating blocking building elements such as columns and walls would increase communication in healthcare environments (Gharaveis et al., 2018; Pati et al., 2015; Zamani, 2018).

Staff indicated that compared to other ICU types, neonates need more care and should be seen and heard from anywhere, anytime. In that sense, the single-room layout of the NICU with solid walls was found inefficient regarding auditory access since it blocks the important, informative, and necessary sound transfer between subspaces. To manage the lack of auditory access, the staff reported shouting more to be heard and kept the patient rooms' doors open, which resulted in a noisier acoustic environment.

The purpose of alarms is to inform the staff about changing life parameters of patients (Lewandowska et al., 2020) and ensure the quality and safety of care (Movahedi et al., 2023). In this study, NICU staff indicated they expected to hear alarms clearly to get informed about patients' status, but they were unsatisfied with their sound characteristics. A growing body of literature focuses on designing better auditory interfaces for healthcare (J. R. Edworthy et al., 2018; J. Edworthy et al., 2017), but the implementation of improved auditory interfaces in the complex healthcare context is slow (Vieira et al., 2020). Two studies focused on the lack of differing alarm sounds creating problems for staff in distinguishing which alarm is sounding and creating difficulties for the staff in learning and recognizing patient problems (J. Edworthy et al., 2011; J. Edworthy et al., 2017). In this study, NICU staff did not mention any recognition problem regarding alarms. Instead, they stated that alarms' high-pitched, rhythmic, constant, and stimulant features evoked feelings of tiredness, depression, anger, annoyance, and unhappiness. These negative responses generated stress, physical exhaustion, sleep disturbance, and ringing in the ears on a long- and short-term basis. However, despite all these problems, staff indicated that NICUs' current alarm-driven sound environment is inevitable, unalterable, and neutral. Therefore, they adapted themselves by accepting the acoustic environment over time.

One of the most interesting contributions of the study is the perception of false alarms. The workload from managing frequent alarms generates mental pressure (Movahedi et al., 2023). Bitan et al. (2004) explored the nurses' reactions to alarms in one NICU and demonstrated that reacting to alarms takes 35% of the working time of a nurse. Studies have shown that up to 80%–99% of all alarms are false or clinically insignificant (Bach et al., 2018; Deb & Claudio, 2015; Purbaugh, 2014) and therefore cause annoyance, frustration, fatigue, concentration loss, and headache (Cho et al., 2016; Sowan et al., 2015). However, even negatively evaluated sound sources can be accepted as part of the environment by the users (Çankaya Topak & Yilmazer, 2022). Since the neonates are more dynamic than other age groups, their movements falsely activated the alarms and created a noisier sound environment. Although staff thought that false alarms could be annoying and physically tiring, they perceived them as neutral for the NICU context and as part of their job because of the inherent mobility of neonates.

Soundscape can be perceived differently based on contextual information or simulation (Mackrill et al., 2013). Staff talking was ranked as one of the most unpleasant sound sources in the NICU environment (Spagnol et al., 2022). However, in this study, the conversation was a contradictive sound source that NICU staff perceived as neutral and part of the environment if the conversation was about patients but perceived negatively if the conversation was nonclinical or personal. The various assessments of staff conversation can be explained by the fact that the same sound source can be evaluated differently in particular contexts.

Although studies have shown that acoustic comfort increases when loudness decreases (Yang & Kang, 2020), the lack of low-level negative sounds is not enough to generate positive soundscapes (Orhan & Yilmazer, 2021). A study found that loud children's noise was accepted as part of the museum experience and generated positive outcomes in the toy-themed museum but was perceived negatively in the art and

archaeology-themed museum (Orhan & Yilmazer, 2021). Likewise, NICU staff indicated they were disturbed when they heard irrelevant sounds, such as telephones and doorbells. The findings align with the previous findings that the morning shift was considered the nosiest (Carvalhais et al., 2021; Santos et al., 2018). However, staff were not disturbed in louder and more complex situations like morning ward visits because of their informative, important, and necessary content.

NICU staff did not expect the acoustic environment to be completely silent. Keyboard sound in open-plan offices while working and computer fan sound in high school labs while studying evoked positive feelings in users (Acun & Yilmazer, 2018; Çankaya Topak & Yilmazer, 2022). Instead of having library-like stillness, low levels of speech about exhibited objects helped visitors to move more freely within the museums (Orhan & Yilmazer, 2021). Similarly, NICU staff expected to hear the vital sounds instead of having quietness and stated that alarms keep them updated about their patients' status. In this way, they were not worried about causing medical errors or endangering patient safety.

The data analyses in this study demonstrate that the NICU environment formed the context, and context significantly affected perceptual attributes of staff and responses to the soundscapes. Based on this study's findings, instead of merely performing the objective measurements of sound levels, the soundscape approach can be used to holistically analyze the acoustic environment of ICUs.

Limitations

This study is limited to one NICU as a case, and the focused user group was the NICU staff who provided patient care. Relatively, the results are limited in generalizability, as they represent the views of 10 female participants who were staff members at a NICU in one university hospital. Nonetheless, the study supports previous findings with perspectives from a hard-to-reach staff population.

Each place has its specific surroundings or structural form and physical, social, and cultural attributes. Each person brings their own demographics, expectations, perceptions, and needs to that place. Changing any of these elements could change the people's soundscape perceptions regarding the context. Therefore, our results may vary for other users and ICU types as they differ in many aspects. Future studies should include various cases, even cross-cultural studies, to gain in-depth evidence to design better ICU soundscapes with globalized findings.

Conclusion

This indoor soundscape study shows that the category of context is the most influential factor in the framework as the context category formed and was affected by the other categories. Built and acoustic environments directly affected staff members' interpretations of the NICU context. The context formed staff members' expectations, perceptions, experiences, coping behaviors, and responses toward soundscapes as either neutral or negative, leading staff members to come up with long-term or short-term outcomes. When the NICU staff were content with the relationship between what they heard and the job-related tasks, they gave neutral responses such as acceptance and adaptation. The sound sources perceived as irrelevant were responded to negatively. Staff indicated that although they expect to hear alarms clearly, specific features of alarms caused several physiological and psychological problems. Improving the NICU soundscapes will enhance staff well-being, which is one of the main aims of ICUs to decrease medical errors and increase patient safety.

Implications for Practice

- Researchers should investigate the impact of proximity and layout on auditory access as much as visual access in NICUs.
- NICU architects should consider staff's communication needs and behaviors while designing subspaces, unit configuration, building systems, and interiors to provide proper auditory access.
- The technology could be used to design softer, deeper, and nonrhythmic alarms

concerning staff expectations. User-focused approaches could help identify the most appropriate alarm sounds for users during the alarm design processes.
- The technology could also be used to design more sensitive medical devices requiring more alarm symptoms to reduce false alarms and prevent staff from its adverse effects.
- NICUs tend to be noisier because the mobility of babies causes false alarms and generates more complex soundscapes. Therefore, designers should consider the type of ICU and context, focusing on specific needs rather than simply applying the same design methodology to each ICU type.
- Researchers should consider qualitative approaches when exploring the impact of the context of soundscape on the perceived built and acoustic environments of NICUs.
- Researchers should not only focus on making objective measurements of the acoustic environment of ICUs but also consider perceptual approaches for a detailed representation of users' interpretations of the soundscape.

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ORCID iD

Cemre Orhan, MFA https://orcid.org/0000-0003-1603-1111

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