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Research Article

Tranquil or desolate? A mixed-methods investigation of patient sound experiences, needs and emotions in single patient ICU rooms

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ABSTRACT

Aims: The sound environment, or soundscape, of intensive care units (ICUs) can be stressful for patients. Soundscapes are defined as acoustic environments as perceived by people. Single-patient rooms mitigate noise, but may deprive patients of essential auditory cues. This might harm basic psychological needs, such as safety. Experiences, needs and emotions regarding soundscapes of single-patient ICU rooms remain unexplored. We aimed to understand how patients experienced these soundscapes.

Methods: This mixed-methods, single-center study involved semi-structured interviews and questionnaires five days after ICU discharge. Patients experienced the soundscapes during their ICU stay, shared experiences in interviews, and selected one to rate on need fulfilment (with a researcher-developed questionnaire), and emotions (with a validated questionnaire). Using thematic analysis, we analyzed interview transcripts by labelling sound-related experiences, sounds, and emotions.

Findings: We interviewed 26 patients. We labelled 259 sound-related experiences, 264 sounds, and 281 emotions, from which six themes emerged: Orientation through sound; Coping with disruptions; Human auditory presence; Monotony and variation; Associations and hallucinations; Communication behind closed doors. Eight patient-selected experiences involved positive emotions. Need fulfilment scores varied: scores were low for communication-related experiences, but relatively high for those involving human presence.

Conclusions: Our findings demonstrated that experiences with single-patient ICU room soundscapes can be positive or negative. For future implementation of such rooms, three insights merit consideration: positive sounds originating from corridors may be unnecessarily removed; alarms in single-patient rooms serve key supportive functions for patients; there is a lack of accessible and appropriate auditory stimulation. We recommend that these insights are taken into consideration to ensure more positive and restorative ICU stays.

Implications for Clinical Practice: In ICUs, balanced approaches that consider both positive and negative aspects of soundscapes may benefit patients in future interventions for noise mitigation. Diversifying the variety of sounds inside patient rooms could further support well-being.

Introduction

The advances in critical care have led to increasingly favorable odds for patients to survive their stay on intensive care units (ICUs) [1], but they may develop long-term psychological, physical and cognitive problems that persist after discharge [2]. Psychological impairments such as post-traumatic stress disorder and anxiety are partially attributable to the environmental conditions of ICUs [3]. In fact, patients, healthcare providers and relatives rate hearing alarms, medical device sounds, and sounds produced by other patients as particularly stressful [4]. These stressors turn ICUs into hostile acoustic environments for both caregiver and patient. For caregivers, this environment can lead to alarm fatigue, still one of the most pressing problems for nurses [5]. Patients suffer from disturbed sleep-wake rhythms [6], potentially resulting in increased incidence and severity of delirium [7]. Sensory deprivation was also identified as a pressing matter in ICUs, leading to a lack of stimulation and loneliness [8]. Improving the acoustic environment of ICUs as perceived by patients, also called the soundscape [9], could instead contribute to favorable outcomes [10,11].

The interventions that have been proposed for the improvement of

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ICU soundscapes have primarily involved the reduction of noise [12], such as single-patient room floorplans or the use of technological solutions (e.g., headphones). These interventions were effective [13], and positively affected patient and staff experience [14–16]. Nevertheless, assigning ICU patients to single-patient rooms could negatively impact patient wellbeing due to the removal of vital auditory cues. ICU patients listen with intent [17] to their auditory environment for cues that fulfill their needs for reassurance, safety, and information [18,19]. Considering trends towards lighter sedation in ICUs [20], other psychological needs, such as pleasure or dignity, could also characterize patients' experiences of soundscapes in single-patient ICU rooms [21]. While ICU soundscapes have been studied in the past [22,23], the experience of soundscapes of single-patient ICU rooms has thus far not been explored. A detailed understanding comprising patient experiences, needs and emotions regarding those soundscapes is therefore necessary to inform future medical innovation in this domain.

To address this, we conducted a mixed-methods study with recently discharged ICU patients who had stayed in single-patient rooms of a state-of-the-art ICU in a Dutch academic hospital. The aim of this study was to gain a rich understanding of how patients experienced the soundscapes of these rooms.

Methods

Design and setting

In this study, we used both qualitative and quantitative methods: we sought to find themes in transcripts of sound-related patient experiences with interviews; we expanded this understanding with questionnaires regarding psychological need fulfilment and experienced emotions. The study followed a convergent mixed-methods design, where qualitative and quantitative data were collected and analyzed in parallel, and then integrated.

The recruitment and study activities were all conducted in Dutch by a male PhD candidate (GL) trained in qualitative research methodologies. During the inclusion period, patient files of all discharged ICU patients were screened by GL for eligibility. Participants were recruited using convenience sampling, based on availability and eligibility according to the inclusion criteria. In the ICU of the hospital, patients reside in single-patient rooms (see Fig. 1) with automatically closing, sound-proofed doors. Also, patients have access to a bedside call bell and an LCD-screen with television and radio channels. The unit follows a standard closed-door policy. Detailed descriptions of sound levels, routines, and policies in this layout are provided in earlier research [13].

Patients meeting the criteria were approached in the general ward of the hospital. During two screening visits at the patient's bedside, GL explained the characteristics of the study. Patients confirmed that they had memories of the sound environment, and gave informed consent. Patients were interviewed by GL during a planned third visit. Aside from the patient and a researcher, a relative was present. Relatives were not formal participants and did not provide answers on behalf of patients. They were present for emotional support and, if needed, to help patients to recall specific details when asked. Their comments, if any, were recorded with their verbal consent. Interview findings were discussed regularly with the other authors to avoid bias and evaluate saturation. Data saturation was assessed by reviewing emerging themes on a weekly basis through team discussions between authors (GL, EÖ, SP), and was considered achieved when three consecutive interviews yielded little to no new themes or insights. Transcripts were not returned to participants for feedback, comment and/or correction. The study was conducted in accordance with the Good Reporting of A Mixed-Methods Study (GRAMMS) framework (Suppl. S1) [24], Standards for Reporting Qualitative Research (SRQR) guidelines [25] and the Consolidated criteria for reporting qualitative research (Suppl. S2) (COREQ) [26].

Population

From February until October 2022 all adult patients that resided in the ICU for 72 consecutive hours or more and remained on a hospital ward between five days and four weeks after ICU-discharge were considered eligible for inclusion. Exclusion criteria were having no memory of the sound environment, not speaking Dutch, having impaired consciousness, and having hearing disabilities. Impaired consciousness was defined as any level of cognitive impairment severe enough to prevent meaningful engagement in an interview, assessed by the treating nurses on general wards at the moment of screening visitation. Hearing disability was defined as clinically diagnosed hearing impairments to both ears that would have prevented the patient from experiencing sound during their ICU stay. Patients who used hearing aids were not excluded. All participating patients provided written informed consent for the collection of demographics, and clinical, audio (transcripts), and questionnaire data.

Data collection

Fig. 2 shows the data collection steps. Prior to a session, patient demographics and clinical characteristics of the ICU stay were obtained from patient files.

The semi-structured interviews were recorded for transcription on a voice recorder. At the start of the interview, a 20-second 360° video was played of an ICU room in the hospital with a headmounted virtual reality (VR) device. Exposure to VR after discharge is studied in ICU survivor

Fig. 1. The hospital's ICU with corridor between rooms (left) and patient room (right).

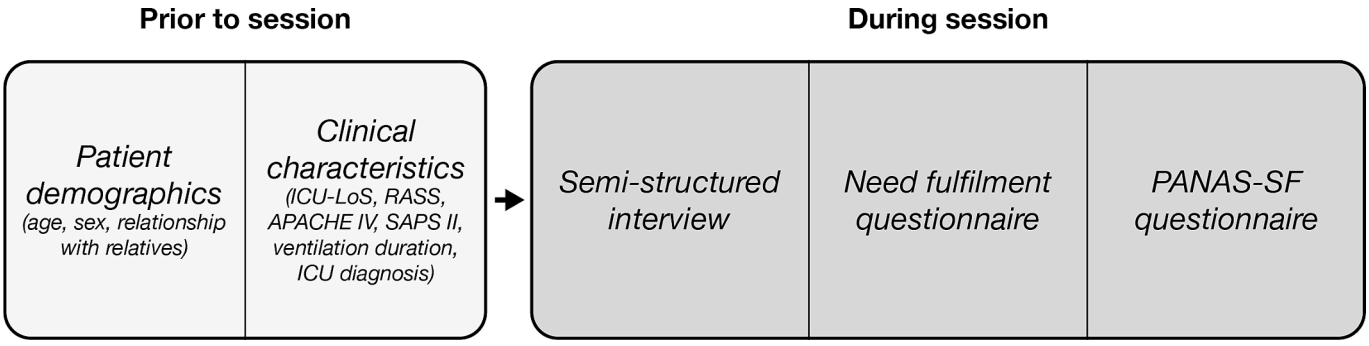

Fig. 2. Steps taken in data collection prior to and during session.

populations [27], and can recreate sensory cues that facilitate autobiographical memory recall [28]. This video was thus meant as a gentle reminder participants of their ICU stay, rather than their stay at the general ward. The visual recording consisted of a static, 360° view from the point-of-view of a patient bed in a single-patient room. The video included minimal audio (i.e., ambient room ventilation and a faint monitoring tone) added in post-processing. To avoid the introduction of bias or stress, the video explicitly did not include any dynamic or potentially distressing visual or auditory cues such as door movement, moving personnel, alarms, or patient interactions. GL informed patients in advance about the video content and its purpose, and offered them the option to skip the video if they felt uncomfortable.

During the interview, participants were informed that they could share as much or as little as they felt comfortable with and could withdraw at any time. An interview guide (Suppl. S3) was followed which consisted of a set of open questions supplemented by follow-up questions. This guide was optimized after pilot interviews with the first three participants. A laddering approach [29] was followed to probe into the reasoning behind participants' answers. Participants were asked which sounds they remembered, to describe sound-related experiences, and select one experience that stood out to them the most. Member checking was employed after interviews by summarizing the answers of participants to each of the questions in the topic guide based on rough field notes. Participants were invited to reflect or clarify this interpretation. As such, any gaps or misinterpretations could be adjusted during data collection to ensure accuracy. At the end of the interview, participants assessed their need fulfilment and emotional state at the time of their selected experience with two questionnaires.

Questionnaires

Previous studies have shown that need fulfilment in user experiences can be measured by scoring statements pertaining to a specific need [30,31]. Psychological needs are understood to be drivers of human motivation. Some of these needs are universally innate to humans across cultures or contexts [32]. These universal drivers are therefore called *fundamental* needs and their fulfilment is associated with enhanced subjective well-being [33]. The fundamental needs included in this study originated from a comprehensive typology consisting of 13 fundamental needs, such as Autonomy [34]. In absence of an existing research instrument for measuring these 13 needs, we constructed a need fulfilment questionnaire: two authors (GL, EÖ) drafted and iteratively revised two statements for each need, e.g., "I felt that I was able to make my own choices" for Autonomy. Statements were sourced from the typology [34]. The 26 statements and translations are provided in Supplementary Materials (S4). These statements were used to assess to what extent the 13 fundamental needs were (un)fulfilled. Statements were in Dutch, preceded by "At the time of this experience I felt …", and were rated on 5-point scales.

The emotional state of participants was measured with the Positive and Negative Affect Schedule – Short Form (PANAS-SF) [35]. This questionnaire is widely used to measure mood or emotion, designed to measure emotional states in relation to current or past experiences. It consists of 20 items, with 10 items for positive affect (e.g., strong, determined) and 10 items for negative affect (e.g., irritable, nervous). The Dutch version of the questionnaire [36] was provided to participants in its validated and original format. Items were preceded by "At the time of this experience I felt …" and were rated on 5-point scales.

Data analysis

The study was underpinned by a methodological orientation of thematic content analysis [37]. The audio recordings collected during the study were anonymized and transcribed verbatim (i.e., maintaining the speaker's exact words). Statements by relatives were transcribed to contextualize patients' experiences but were not included in analysis. We studied the transcripts with the inductive thematic analysis method to understand how patients experienced the ICU soundscape during their ICU stay. In this process, quality guidelines for thematic analysis by Braun and Clarke were followed [38]. Transcripts were analyzed in ATLAS.ti (https://atlasti.com/).

The analysis of transcripts was divided into four steps. First, GL identified sections where participants mentioned sound-related experiences. Second, authors (GL, EÖ) assigned codes for each sound-related experience (e.g., nurse entering), sound (e.g., door creaking), and emotional state (e.g., annoyed) mentioned by the participant. Third, these initial codes were discussed among authors (GL, SP, EÖ), and reduced in number through elimination and combination of identical or related codes. Fourth, two authors (GL, EH) looked for patterns in codes and developed key themes. These themes were refined and discussed among all authors to ensure that the themes accurately represented the experiences. Disagreements were discussed to reach a consensus, reducing individual bias and increasing the consistency of thematic identification. We assessed co-occurrences of codes for sounds and emotional states within each emerging theme in ATLAS.ti, an approach recommended in qualitative research to explore relationships in a non-quantitative manner [39]. This allowed us to determine what characterized each theme in terms of sound sources and emotional responses, contributing to a richer interpretation of the data.

Based on the scores of participants regarding their one selected sound-related experience, a need fulfilment (NF) variable was calculated for each of the thirteen needs from the need fulfilment questionnaire. NF was calculated by averaging the ratings for the two statements per need, resulting in an NF score between 1 and 5. For each participant, a positive affect (PA) and negative affect (NA) variable was also calculated from their responses to the PANAS-SF questionnaire. This was computed by cumulating the scores given by participants for negative and positive items, resulting in a PA or NA score between 10 and 50 [35]. Means and standard deviations were calculated for NF, PA, and NA. These variables were tested against the demographic/clinical characteristics of the sample for possible significant correlations with Pearson's r or Spearman's rho.

To integrate the qualitative and quantitative data, a structured approach was used in which themes resulting from thematic analysis of interview transcripts were compared with questionnaire responses. First, sound-related experiences selected by participants were categorized under one of the themes by the authors (GL, SP, EÖ). Second, corresponding NF, PA, and NA scores were assigned to each experience based on participant responses. Third, average NF, PA, and NA scores were computed per theme, allowing for comparison of need fulfillment and emotional state between themes. This provided a comprehensive interpretation of how patients' sound experiences in single-patient ICU rooms aligned with their psychological needs and emotional states.

Results

Demographics and clinical characteristics

A total of 946 discharged ICU patients were screened of which 916 patients either did not fulfill inclusion criteria or were excluded based on the screening visits (see Fig. 3). Of the remaining 30 patients, 3 participants took part in pilot sessions to optimize the interview guide, and one participant was excluded due to fatigue, resulting in a total sample of 26 participants.

Their demographics are shown in Table 1. Additionally, Table 1 shows clinical characteristics related to ICU stay, including ICU length of stay (ICU LoS), duration of sedation, and duration between discharge from the ICU ward and our interviews. The distributions of these durations (Suppl. S5) and the relationship between ICU LoS and the ICU LoS not spent in unarousable or deep states of sedation (RASS ≥ -3) (Suppl. S6) are included in the Supplementary Material. Half of the participants were within an age range of 48 to 66 years. APACHE IV scores indicated moderate levels of illness severity. Additionally, a high proportion of the sample was mechanically ventilated (88 %), nearly half were transplant patients (42 %), and a quarter (27 %) had cardiovascular diagnoses. No significant correlations were found between demographic or clinical characteristics and questionnaire measurements of need fulfilment and emotional state.

Table 1
Demographics of participants paired with clinical characteristics related to ICU stay.

Demographic/clinical characteristic	N = 26
Sex, n (%)	
Male	18 (69)
Female	8 (31)
Relative relationship, n (%)	
Partner	18 (69)
Sibling	1 (4)
Parent	2 (8)
Child	5 (19)
Age, years (median [IQR])	60.5 [48.3–66]
ICU Length of Stay (LoS), days (median [IQR])	8.0 [3.8–29.8]
ICU LoS spent sedated (RASS < −3), days (median [IQR]) [a]	1 [0–6]
ICU discharge to interview, days (median [IQR])	8.9 [6.7–12.5]
APACHE IV score (median [IQR]) [b]	57 [48–73.3]
SAPS II score (median [IQR]) [c]	36 [29.8–42.3]
Mechanically ventilated, n (%)	23 (88)
Mechanical ventilation duration, hours (median [IQR])	35 [26–245]
Diagnosis at ICU admission, n (%)	
Transplant	11 (42)
Cardiovascular	7 (27)
Other	15 (58)

IQR: Interquartile Range.
[a] Richmond Agitation-Sedation Scale (RASS) score of −3 corresponds to "Moderate sedation".
[b] Acute Physiology and Chronic Health Evaluation (APACHE) IV, higher scores indicate greater disease severity.
[c] Simplified Acute Physiology Score (SAPS) II, higher scores indicate more severe illness.

Themes

Data saturation was reached after 26 patient interviews. Each session lasted approximately 30 min (median = 31.4, IQR = [28.0–35.9]) with participants spending around 15 min being interviewed (median = 17.3, IQR = [15.0–20.6]), and the rest of the time spent on the questionnaires. Eleven relatives provided contextual commentary (i.e., 1–3 comments)

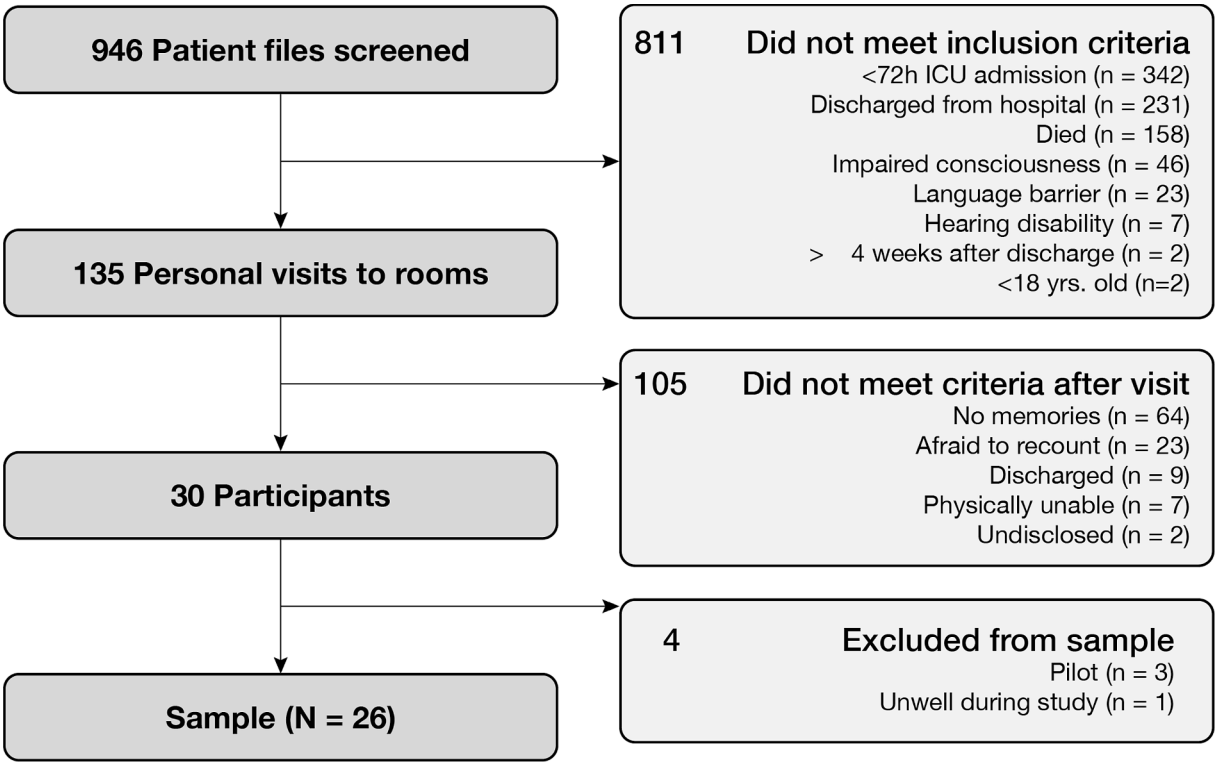

Fig. 3. Flowchart of inclusion.

Table 2
For each of the six themes found in the thematic analysis: related co-occurring sounds and emotions, a translated representative quote, and the number of transcripts that mentioned the theme.

Theme	Co-occurrences (N)		Representative quote
	Sounds	*Emotions*	
Orientation through sound	Silence (14), infusion pump alarms (9), alarms (unspecified) (9)	Lost (7), Fearful (5)	*P12: 'Sound is your only support. You orient on sound, and you are worried about what is going on. … You have nothing to orient on, so you are looking for elements to hold on to.'*
Coping with disruptions	Infusion pump alarms (17), alarms (unspecified) (13)	Annoyed (23), Frustrated (8)	*P8: 'The annoying part … is that you have so much difficulty getting to sleep, and then you are being woken up by that pump. Yes, that is so annoying. That is just the opposite of what you want.'*
Human auditory presence	Corridor (8), footsteps (7), silence (7)	Pleasant (12) Annoyed (7)	*P15: '… I found it a calming feeling when I heard voices from the hallway. … you are alone in a room…. and yes, that was just like "Yes, I am not lying here all alone".'*
Monotony and variation	Music (9), infusion pump alarms (6)	Pleasant (8), Annoyed (5)	*P25: '…music was almost the only thing … for distraction. Reading did not work, watching TV was too tiring, so … the distraction of music was actually the only thing that offered relief.'*
Associations and hallucinations	Infusion pump alarms (4), patient monitor alarms (3)	Fearful (4), Annoyed (3)	*P18: 'You see animals that do not exist. … those sounds were not made by those animals, but by the machinery … annoyance and … a lot of fear. … The sound accentuated everything, just like in a movie.'*
Communication behind closed doors	Silence (11), infusion pump alarms (10), alarms (unspecified) (10)	Fearful (17), Lonely (15)	*P17: '… my alarm bell fell on the ground … I started shouting … your fear starts building, if something really happens, then they do not come … I do not think that everybody finds it pleasant having that door closed.'*

to assist patients in recalling details. None of the participants chose to skip the video. In total, we coded 259 sound-related experiences, 264 sounds, and 281 emotional states. The applied codes and their frequency of (co–)occurrence have been included as Supplementary Materials (S7).

By analyzing the coded sound-related experiences for patterns, we found six recurring themes: 1. Orientation through sound, 2. Coping with disruptions, 3. Human auditory presence, 4. Monotony and variation, 5. Associations and hallucinations, and 6. Communication behind closed doors (Table 2). In co-occurrence analyses for each theme the most frequently mentioned sounds and emotions were found. In Table 2, the themes and most occurring sounds and emotions are shown together with a representative quote, and the number of transcripts the theme was based on.

Theme 1: Orientation through sound

Sixteen participants described the soundscape as unfamiliar, unusable and without meaning, because it mainly consisted of unrecognizable sounds. As their primary source of orientation and information, participants emphasized how important their hearing was to them in early stages of their ICU stay after waking from sedative states. But listening to the few sounds present in their rooms—such as infusion pump alarms—they were unable to identify their meaning. Participants thus experienced the soundscape as empty or silent, regardless of the sounds present. This resulted in states of fear and alertness. Contrastingly, participants experienced alarms as meaningful by learning that nurses will respond. Thus, these sounds also caused feelings of safety and anticipation.

Theme 2: Coping with disruptions

Twenty participants expressed their annoyance and frustration about sounds disrupting the soundscape. These disruptions made participants feel restless and annoyed and kept them in a state of wakefulness. The participants did not understand why it was necessary that infusion pump alarms went off so often in the room, which then had to be resolved by clinical staff. Awakening or being kept from sleep by infusion pump alarms and staff entering caused anger and annoyance. Thus, participants remembered that disruptions were not only caused by alarm events. When the sliding door of their room was opened, the soundscape would change, exposing them to footsteps, voices and laughter of clinical staff.

Theme 3: Human auditory presence

Listening to the presence of people formed a recurring topic for 19 participants. The experiences involved sounds of clinical staff such as footsteps, impacts of objects and speech, but also sounds originating from other patients. Listening to voices of clinical staff offered participants a sense of relatedness offering relief from the isolation of the room. Others mentioned feeling safe due to these sounds, confirming the availability of support in their vicinity. But it could also be experienced as annoying, especially during the night or when attempting to fall asleep. Sounds initiated by other patients, such as shouts, were also considered as negative.

Theme 4: Monotony and variation

Thirteen participants made statements regarding the lack of variety and monotony of the soundscape at certain times of day. They experienced periods without direct interaction when relatives were not present and visits by clinical staff were less frequent due to fewer necessary care activities and closed-door policies. Participants only had a limited selection of sounds to listen to, causing them to feel weary. Moreover, the periods of time spent in absence of a wider variety of sounds or visits caused participants to involuntarily focus their attention on annoying sounds, such as the sound of a clock in their room. The participants felt that their options to be distracted from this annoyance and monotony were limited, due to the effort it took to listen to radio or watch TV for extended periods of time. Nevertheless, some participants were successful in distracting from or masking the sounds they preferred not to hear.

Theme 5: Associations and hallucinations

As the sources of sounds were unclear to participants in some stages of their stay, they misinterpreted the meaning of sounds in the ICU room. Eight participants mentioned associating sounds with other sound sources, such as associating air flows with rain or voices. Some participants experienced these misinterpretations as positive, since the meaning they connected to these associations was connected to positive experiences or memories. Contrastingly, others experienced intensified hallucinations or melodies that would remain stuck in their heads.

Theme 6: Communication behind closed doors

Nineteen participants expressed feelings of powerlessness and fear due to being secluded. They explained that failed efforts to communicate or get attention from behind closed doors, except with the alarm bell, led to the feeling that if something would go wrong, nobody would notice. Consequently, the alarm bell became a lifeline to the outside world, and its misplacement evoked panic. The participants felt dependent and were not confident they could reach the ones they depended on. Instead, they felt abandoned. Pressing the alarm bell provided no feedback that it had been received or heard. Indicative of this lack of reassurance and trust, when alarms would go off participants felt they had to notify

clinical staff by pressing their alarm bell. The following minutes were stressful.

Need fulfilment

In the interviews, participants were asked to select one sound-related experience and scored their fulfilment of needs and emotional state. The selected sound-related experiences and their corresponding questionnaire scores were assigned to one of the six themes based on their codes. See the Supplementary Materials for the distribution of selected experiences per theme and central tendency of need fulfilment scores (S8). In Fig. 4, the mean need fulfilment scores per theme were plotted and arranged into spider-plots.

The spider plots signified several differences in fundamental need fulfillment between different themes. Human auditory presence (Fig. 4c) shows high scores on several axes, such as Relatedness and Community. This suggested that experiences selected by participants within this theme involved a high fulfilment of these needs. In contrast, Communication behind closed doors (Fig. 4f) yielded low scores across axes, indicating that participants tended to rate that experience as less fulfilling in terms of their needs. Orientation through sound (Fig. 4a), Coping with disruptions (Fig. 4b), Monotony and variation (Fig. 4d), and Associations and hallucinations (Fig. 4e) showed mixed need profiles. Scores for Stimulation were consistently low, suggesting that participants did not experience the fulfilment of this need in any of the selected sound-related experiences.

Emotional state

The calculated cumulative Positive Affect (PA) and Negative Affect (NA) scores are included in the Supplementary Materials (S8) and were plotted as datapoints shown in Fig. 5. The datapoints were labeled with each participant's selected sound-related experience, a shape indicating the theme.

The scatterplot illustrates the distribution of experiences across both PA and NA with the axes representing PA (x-axis) and NA (y-axis). The data points are spread across the plot, with experiences from the themes appearing in various clusters in the graph. Eight positive and eighteen negative experiences were found. Positive experiences tended to cluster in areas with higher PA and lower NA scores in the bottom right involving feelings of reassurance and happiness. In contrast, negative experiences were mainly clustered in the top half of the plot with lower PA and higher NA scores. These experiences involved feelings of annoyance, fear, and nervousness.

Discussion

In this mixed-methods study, we aimed to gain a rich understanding of how adult ICU patients experienced the soundscapes of single-patient ICU rooms. Through interviews, themes were identified related to

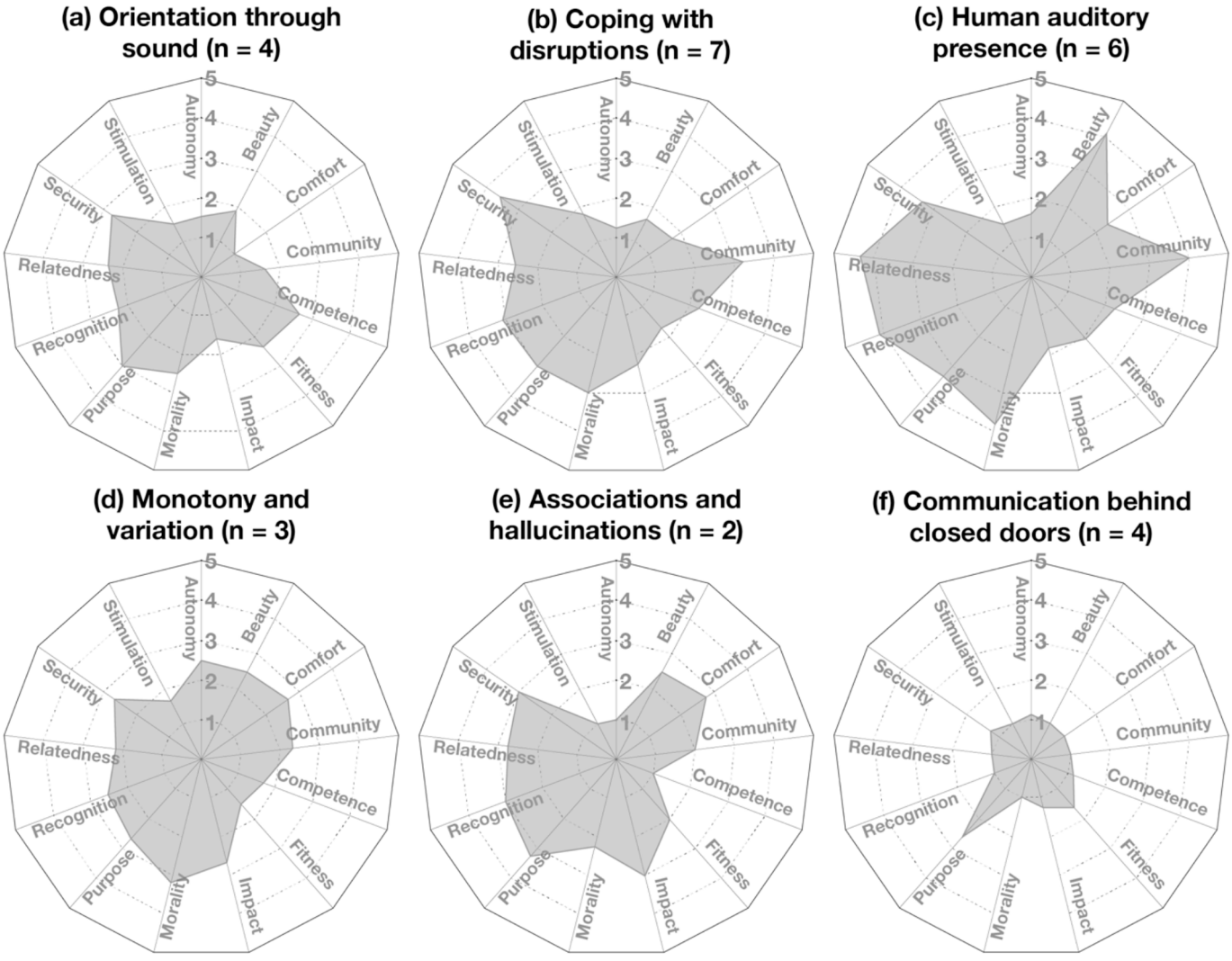

Fig. 4. Spider plots of mean need fulfilment ratings for thirteen needs, divided by theme.

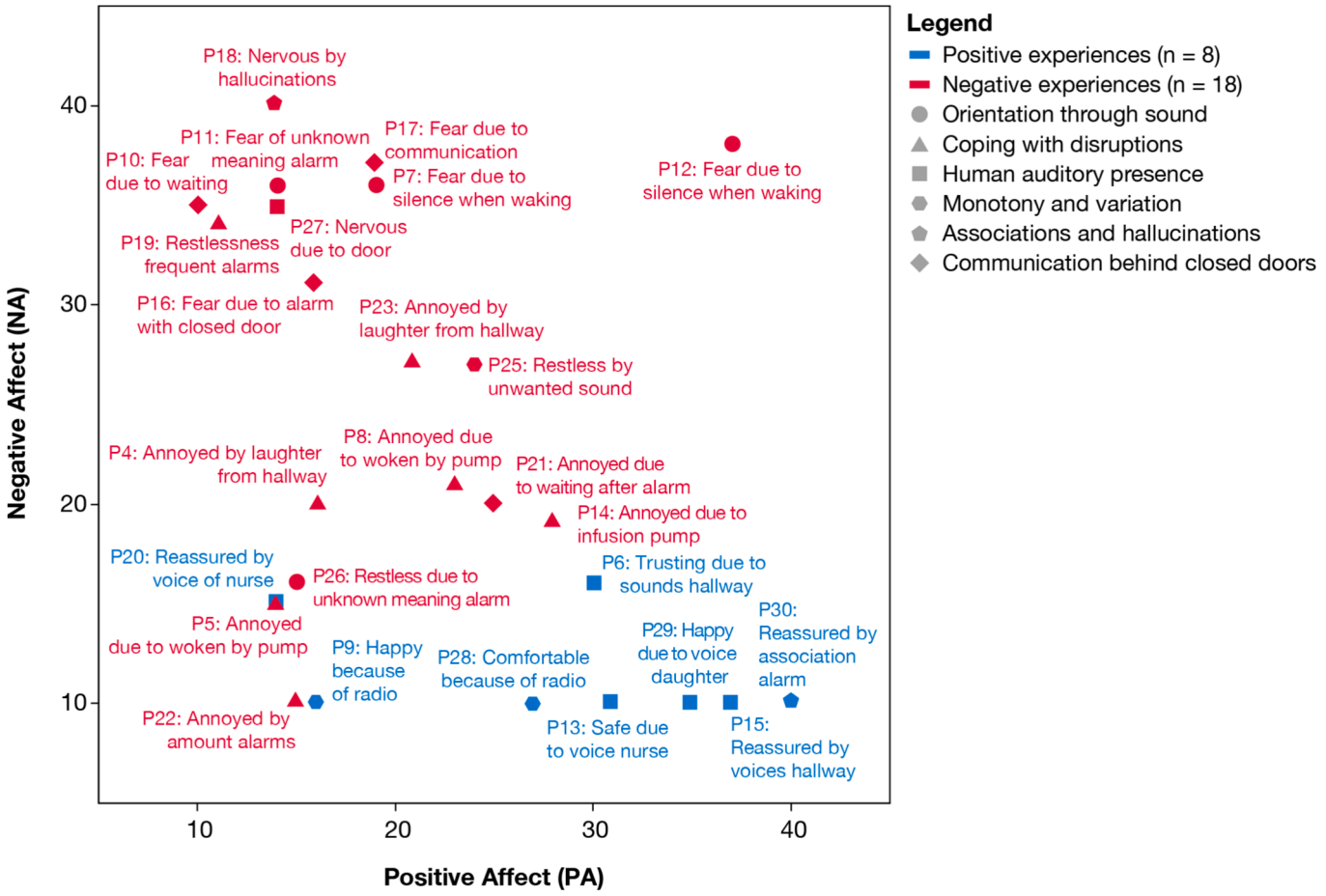

Fig. 5. Plot of computed Positive Affect (PA) and Negative Affect (NA) scores for each chosen sound-related experience.

patients' sound-related experiences, while questionnaires on need fulfillment and emotional experiences expanded this understanding. By integrating qualitative and quantitative findings, the themes, needs and emotions we encountered three main insights.

First, our findings suggested that single-patient ICU rooms may be overly reductive of sounds that originate from outside the room. Participants shared negative experiences with sounds caused by clinical staff, but those sounds also provided reassurance and comfort. This ambivalent stance towards human sounds was found in previous research in open-bay ICU room layouts as well [23]. However, single-patient rooms isolate patients from both the positive and negative aspects of this outside soundscape. These qualitative findings aligned with quantitative results regarding the needs and emotions of participants: the fulfilment of all needs in theme 6: Communication behind closed doors (Fig. 4f) was minimal, whereas in theme 3: Human auditory presence (Fig. 4c), fulfilment of several needs (i.e., Beauty, Community, Comfort, Recognition, Relatedness, Security, and Purpose) was high. Likewise, high scores of PA were found for experiences related to human sounds, see Fig. 5. Most current innovations view human sound as inherently negative and obtrusive [12]. But our findings suggest that future innovations to ICU soundscapes could take a more balanced approach. Interventions such as flexible open-door policies could be implemented as a facet of larger, multimodal patient-centered care strategies, such as the eCASH concept [40]. Those policies could reduce the incidence and duration of delirium with improved sleeping patterns [41] due to diurnal changes in average sound levels [42,43].

Second, our results indicated that alarms in single-patient ICU rooms might serve a supportive function that should not be overlooked. Experiences of participants with alarms included both negative and positive aspects. Infusion pump alarms were mainly mentioned as their source. The occurrence of alarms in negative sound-related experiences was expected since it forms a major contributor to sound levels in ICUs [12,44]. More unexpected were positive experiences regarding alarms. Safety attributed to alarms has been observed before [23]. However, our findings indicated that alarms in single-patient ICU rooms may serve a communicative and informational purpose, offering relief and anticipation. The scores of needs and emotions provided further clarifications. High need fulfilment was observed in theme 2: Coping with disruptions (Fig. 4b), while seven out of 18 negative experiences were related to this theme (Fig. 5). Furthermore, in line with previous ICU soundscape studies [22,23], participants who experienced the soundscape as empty reported low need fulfilment (Fig. 4a) and negative emotions (Fig. 5). This should therefore be taken into account for future innovations, since current medical device manufacturers work towards new interoperability standards to jointly silence alarms in patient rooms [45]. By directing alarm sounds outside of patient rooms, such standards enable the creation of a "silent" ICU. Our results support that alarm reduction would indeed be a sensible intervention, but that the standalone removal of alarms could prove less effective for improving patient experiences. In absence of alarms in silent ICUs, their provision of safety, relief, and anticipation should be offered to patients in other ways. Future research and design efforts could investigate how to optimally provide this. Also, future research should be conducted to confirm the merit of providing such systems alongside alarm reduction solutions.

Finally, our findings showed that while the single-patient ICU rooms offered some sources of auditory stimulation, they may lack accessible auditory stimulation that meets the preferences of patients. Room soundscapes included alarms, air conditioning, and mechanical ventilation. Television and radio were available through digital interfaces on LCD-screens. Several participants used these interfaces, e.g., for

distraction with the classical music radio channel. For those participants, their interactions led to positive user experiences (see Fig. 5), as indicated by high positive affect scores. An explanation could be the relatively high fulfilment of the need for Autonomy in theme 4: Monotony and variation (Fig. 4d), compared to other themes. This is consistent with previous findings: being able to adjust hospital environments promotes patient comfort and satisfaction [46]. Nevertheless, such experiences may be accessible to only a select few. Physical impairments, delirium, or sedation may require others to operate these LCD-screens instead. But relatives can only be present during visiting hours and involvement of nurses implicates additional workloads. Further, overall low fulfilment of Stimulation (see Fig. 4) suggested that auditory stimulation was insufficient in each experience, consistent with earlier findings [8,47]. This may indicate that auditory stimulation should not only be present, but also match the preferences of patients. For resting, patients might desire music with low beats-per-minute; for distraction during clinical procedures such as endotracheal suctioning, upbeat music may be preferred. Studies have explored the benefits of personalized playlists in ICUs tailored to musical preferences [48,49]. By relying on patient preferences, such measures may enhance individuality by supporting their need for Autonomy [30,34]. However, future research efforts should investigate how such preferences may be related to supportive functions for patients (e.g., distraction). Future innovations could thus provide patients with personalized, and contextual listening experiences [50].

Concluding, our findings provide an optimistic perspective of current soundscapes of single-patient ICU rooms. Presently, they may be consequences of treatment and life support. But in the future, these soundscapes could become a functional and supportive element of ICU stays. By supporting the psychological needs of patients, more positive soundscape experiences and favorable patient outcomes may lie ahead.

Limitations

The activities of the present study were conducted in the ICU of a single academic hospital. As differences might exist in workflows, protocols, organizational structures and layouts between hospitals, multicenter studies with different ICU departments with single-patient rooms could provide a more comprehensive overview. Also, the composition of participants included in the sample should be considered: of the surviving and physically able proportion of patients, a large number (n = 64) we visited could not remember any of the sounds of their stay in the ICU and were subsequently excluded. Other patients were excluded for other reasons. Participants were of a similar age (i.e., between 48 and 66 years old), and the severity of patient conditions as indicated by APACHE IV scores were mostly moderate; additionally, the high proportion of ventilated patients (i.e., 88 %) and transplant recipients (i.e., 42 %) should be considered. However, this focused cohort provided valuable thematic insights regarding soundscape experiences, needs, and emotions in single-patient ICU rooms, which could be explored further in future studies with regards to ICU populations with different clinical profiles.

The time participants spent awake (i.e., not in deep or unarousable states of sedation) in the single-patient ICU rooms could be expected to influence which/how many sound-related experiences they shared in the interviews. For example, it is possible that a group of patients who were awake for only a short period would only form memories to a limited set of similar events. We acknowledge the substantial role that this awake-time bias could play. In our sample however, participants spent at least a full day awake (up to 179 days). Additionally, we confirmed with recruited patients that they indeed had active memories to their ICU stay. Nevertheless, our insights should be considered in light of these limitations. Finally, patients may experience memory distortion with regards to their ICU experiences [51]. This was minimized by involving relatives and conducting interviews with patients soon after their ICU stay (i.e., five days) to ensure proximity to the experiences themselves. Despite these measures, in studying human experiences some recall bias may remain. Future studies could collect additional data such as from ICU diaries to increase the overall accuracy of shared experiences.

Due to practical considerations—minimizing participant burden—quantitative measures were collected for only one selected experience per participant. Not all experiences shared in interviews were thus explored through a mixed-methods lens. Still, aligning these experiences with identified themes led to a comprehensive understanding of soundscape experiences. Future research could adopt a deductive approach to investigate a larger number of experiences.

Conclusion

In this mixed-methods inquiry, we explored how patients experienced soundscapes of single-patient ICU rooms. We found that for future improvements of ICU soundscapes, a more balanced approach regarding noise mitigation may be required to better accommodate the psychological needs of patients. Our results showed that indiscriminate eliminations of sound can lead to stressful experiences. Thus, interventions such as sound-proofed doors should only be implemented with the awareness that certain positive elements are removed as well. Also, efforts should be made to diversify the variety of sounds in single-patient ICU rooms with the reintroduction of new sounds, such as music or natural sounds. With the insights of this study, future interventions could perhaps turn single-patient ICU rooms into a place of tranquility rather than desolation.

CRediT authorship contribution statement

Gijs Louwers: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Diederik Gommers:** Writing – review & editing, Supervision, Resources, Conceptualization. **Esther M. van der Heide:** Writing – review & editing, Supervision, Formal analysis, Data curation. **Sylvia Pont:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization. **Elif Özcan:** Writing – review & editing, Supervision, Project administration, Methodology, Formal analysis, Conceptualization.

Ethics approval

All patients who participated provided written informed consent according to the protocol of this study, approved by the Institutional Review Board of the Erasmus Medical Center on 11th of November 2021 (MEC-2021–0758). Participants could withdraw consent at any time. All procedures were in accordance with the ethical standards of the Erasmus MC research committee and with the 1964 Helsinki Declaration and its later amendments.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Gijs Louwers reports financial support was provided by Philips. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.iccn.2025.104031.

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