Being critically ill and surrounded by sound and noise

Patient experiences, staff awareness and future challenges

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"There is no such thing as an objective listening of sounds"

Tania Zittoun (2012)

ABSTRACT

The sound environment in the ICU patient room is known to be poor and demanding. However, little is currently known about how patients recall and experience the sounds that surround them. Furthermore, staff knowledge of the field and their suggestions for improvements are of interest. Therefore, the overall aim of this thesis was to illuminate how critically ill patients experience being surrounded by sound and noise. In addition, its aim was to explore ICU staff's knowledge and suggestions for improvements regarding the sound environment and to investigate the feasibility of a complex sound intervention in an intensive care context. A multiple-method approach was used in this thesis. In Study I, sound measurements for 13 patients were taken, while, at the same time, early signs of delirium were identified. Qualitative research interviews were conducted after discharge, and all data were analyzed using content analysis. Study II involved the same interviews; however, they were analyzed using the phenomenological hermeneutical method. Study III consisted of statistical analysis of a questionnaire answered by 305 ICU staff from nine ICUs. Furthermore, qualitative research interviews with 20 ICU staff were performed and analyzed using content analysis. Study IV was conducted in the context of an intervention project consisting of two two-bed ICU patient rooms which were originally identical. One of the rooms was equipped with sound- absorbents and the other remained in its original condition. Sound measurements were performed continuously, and ICU delirium was estimated daily using the CAM-ICU instrument. Observations were performed during the entire data collection time to assess feasibility before a full-scale study.

Sound measurements in the ICU patient room showed that critically ill patients are exposed to high levels of sound and intermittent noise day and night. Despite critical illness, patients remembered many sounds from their ICU stay, and while some sounds were perceived as positive, others were experienced as disruptive and caused feelings of helplessness and fear. Sounds came suddenly and unexpectedly, which meant that they were completely unpredictable. Staff working bed-side have little knowledge regarding sound and noise and the adverse health effects they can have. However, staff also made suggestions for improvements. Conducting an RCT with continuous sound measurements in an ICU setting is complicated and time-consuming, but it is feasible.

Key words: critical illness • noise • vulnerability • experience • caring • care environment • intensive and critical care • knowledge

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LIST OF PAPERS

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III Johansson L, Knutsson S, Bergbom I, Lindahl B. Noise in the ICU Patient Room - Staff knowledge and clinical improvements.
In manuscript

IV Johansson L, Lindahl B, Knutsson S, Ögren M, Persson Waye K, Ringdal M. Feasibility of a Complex Sound Environment Intervention in ICU.
In manuscript

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ABREVIATIONS

ICU	Intensive care unit
CCU	Coronary care unit
LoS	Lengths of Stay
SAPS III	Simplified Acute Physiology Score
CAM ICU	Confusion Assessment Method for the ICU
SPL	Sound Pressure Level
Leq	Equivalent Continuous Noise Level
dB	Decibel
RT	Reverberation Time
RCT	Randomized clinical trial
SI	Le Système International d'Unités, the international system of units

DEFINITIONS

In this thesis the following definitions are taken from the Oxford English dictionary (2014):

SOUND	Vibrations that travel through the air or another medium and can be heard when they reach a person's or animal's ear- A thing that can be heard.
NOISE	A sound, especially one that is loud or unpleasant or that causes disturbance.
ACOUSTICS	The properties or qualities of a room, building, or other place in transmitting sound, esp. with respect to reverberation time

INTRODUCTION

Every year about 45.000 people in Sweden need care and treatment in an intensive care unit (ICU) due to severe injury or critical illness (SIR, 2014). A variety of diagnoses, types of injuries and lengths of stays (LoS) are found in the ICU, meaning that patient conditions vary; some patients are conscious, others are unconscious. Today, about 93% percent leave the ICU alive and about 85% are still alive 30 days after being admitted to an ICU, indicating that Swedish intensive treatment is successful (SIR, 2014). However, these numbers do not provide the full picture. In this thesis, it is argued that the quality of the ICU stay is important meaning that medical care needs to be augmented with a holistic approach; the human being should be seen as a complex individual with many needs that influence wellbeing and the outcome of critical illness. One such basic need is the opportunity for peace and quiet, rest and sleep and therefore, sound and noise are factors that should be considered when developing care and caring. At the center of this study, and the patient's temporary home, is the ICU patient room, a complex place with high staffing levels and containing a lot of technical equipment. Unfortunately, in the ICU, where historically most activity has been focused on life-supporting actions (Celik, Oztekin, Akyolcu, & Issever, 2005), there has been little interest in developing restorative environments which could impact recovery. The goal of caring is to preserve and take action for patient health, and recent research has shown that in order to meet these basic needs, care can be further developed and optimized.

Since critical illness often influences patients' alertness for shorter or longer periods and places them in a vulnerable position, it is likely that noise is particularly inappropriate. However, currently, there is a lack of knowledge concerning critically ill patients' experiences of being cared for surrounded by high sound levels and noise that disturbs them. Only a few studies have investigated the effects of sound and noise in the ICU. This is probably because of the uniqueness of the ICU environment which is known to be both complex and unpredictable; it is around the clock activity, high staffing levels and extensive and constantly evolving technical equipment. To conduct comparative studies in an ICU is, therefore, both difficult and demanding. A further question concerns staff awareness and whether staff can improve the environment and as a result, the care.

In recent decades, the acoustic conditions in ICU areas have been described and investigated in the acoustic, nursing and medical sciences and the results have ascertained that the ICU sound environment is of an inferior quality; more about this research will be presented later. Remarkably, these results have not generated clinical interest. According to an American study, sound pressure levels in hospitals have even increased in the past 40 years (Busch-Vishniac et al., 2005). These findings indicate that there is much left to do in terms of improving the sound environment, and one question that arises is whether the soundscape in the ICU harms patients more than it contributes to their health and recovery. Another question is whether staff contribute to this sound environment and if they can influence these conditions.

It has been shown that many patients experience discomfort, including poor sleep, delirium and unreal experiences during their stay in ICU (Arend & Christensen, 2009; Freedman, Gazendam, Levan, Pack, & Schwab, 2001; Granberg, Bergbom, & Lundberg, 1999; Karlsson & Forsberg, 2008; Lof, Berggren, & Ahlstrom, 2006; M. Ringdal, Johansson, Lundberg, & Bergbom, 2006; B. Roberts & Chaboyer, 2004; Rose, Nonoyama, Rezaie, & Fraser, 2014). Delirium has been shown to be associated with higher mortality rates and longer stays (Ely et al., 2004) and the unreal experiences, mostly experienced as unpleasant and frightening, often persist in forms of memories for month or years after discharge (Zetterlund, Plos et al. 2012). Traditionally, most patients in the ICU are deeply sedated. Therefore, the general opinion has been that the physical environment of the ICU patient room, including noise, is an unimportant and/or taken-for-granted factor and, consequently, nothing to take an interest in or spend money on. In an ICU, the focus is on survival and the patient is expected to be satisfied if he/she leaves the ICU alive. However, things are changing (Egerod, 2009). Research has found that recovery is not meeting expectations or reaching desired goals; muscular dystrophy, cognitive problems and psychological disorders are common for a long time after discharge (Herridge et al., 2003; C. Jones, 2014; Livingston, Tripp, Biggs, & Lavery, 2009; Van Rompaey et al., 2009). In recent years, several studies have shown that deep sedation can cause unwanted side effects and as a result higher costs (Stevens et al., 2007; Strom, Martinussen, & Toft, 2010; Treggiari et al., 2009), and the trend is now towards a more restrictive approach to sedation. This also applies to ventilated patients (Bourdin et al., 2010; Karlsson & Forsberg, 2008). This means that patients today, and even more so in the future, will be relatively conscious when in the ICU and, therefore, more susceptible to sensory input such as sound and light. Consequently, the physical environment will become more important and has to be seen as a tool for supporting patients' restorative processes. That the patient is sedated can no longer be used as an excuse for a poor acoustic environment. The design of the physical environment must be integrated in the care; though more research is needed in this area. Nonetheless, if this is to be the modus operandi of the future, it will place greater demands on both ICU staff and patients surroundings.

According to Swedish health care law (Svensk författningssamling HSL 1982:763), the health care system is required to provide patients with adequate and good care. This means that there is a need to develop knowledge concerning what good care comprises, what it is that contributes to good care and identify existing obstacles (Bergbom, 2014). Moreover, a more holistic approach is needed if the patients in the ICU patients are to receive the care that health the care system is required to provide. Therefore, the main purpose of this thesis was to identify and describe aspects that influence the sound environment in an ICU patient room, aspects that affect patient health and recovery. Furthermore, the question was, is the ICU patient room a caring environment for the critically ill patient or, in the worst case scenario, does it actually harm the patient? To clarify this, it was important to elucidate this issue from different perspectives and to acquire more knowledge about the role of sound and noise in this specific context. Additionally, for future clinical implementation, it was also necessary to investigate the influence of various components such as staff knowledge, suggestions for improvements and the feasibility of a complex sound intervention in an ICU.

BACKGROUND

Sound

Sound and its significance for humans have been studied and debated in many disciplines over the years although not as much in the caring and nursing disciplines. Therefore, a relevant exploration of the importance of sound and noise follows. This gives a picture of how sounds interact with healthy people in general, seen from a psychological, physiological, historical and acoustic perspective.

Sound - a physical perspective

Many things can create sounds; the strings of a piano, two metal plates clashing, the tapping of heels and toes when dancing, and so on. However, one factor that is necessary for a body to be a source of sound is its ability to vibrate. Therefore, a "sound event" occurs when something happens that causes something else to be set in motion, and the event can be transmitted through or along a medium. Air is the most common medium and, in this thesis, the one of interest; but other media such as water and steel rails can also transmit sounds. Vibrations create waves and these waves get a transfer of energy through the medium in the direction in which the wave is traveling. Moreover, the wave has a frequency cycle and speed that depend on the composition of the medium. The frequency is the rate at which the wave repeats itself and is measured in cycles per second or Hertz (Hz) (Speaks, 1999).The range of human hearing is between ca 20 Hz and 20. 000 Hz, and frequencies between 2.000 and 4.000 Hz are the most important for understanding speech (Goldstein, 2009; Keefe J, 2004) (Figure 1). The speed of a wave depend on the characteristics of the medium and, in the air at 20°C, the speed of a sound-wave is 343 m/s. Sound pressure is the local pressure caused by a sound-wave. The SI unit for sound pressure, p, is Pascal (Pa). What our ears perceive are, therefore, variations in the air pressure around us (Speaks 1999).

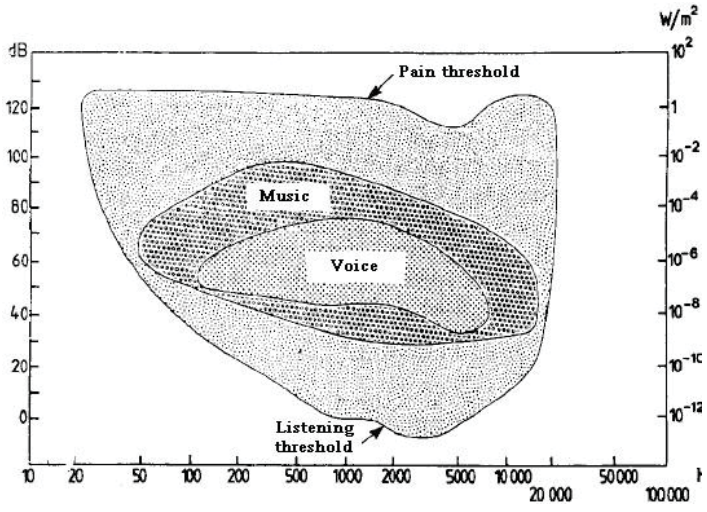

Figure 1. A picture of the domain of perception and the thresholds of pain and listening (Acoustics/Fundamentals of Psychoacoustics, 2014, October 7). The thresholds are often generically called Fletcher-Munson curves after the original work by Fletcher and Munson (1933).

The dynamic of the ear is so vast that the gap between the sound pressure amplitude of the lowest sound and the highest sound that an ear can register is more than a million Pa. Therefore, it is more practical to use the logarithmic variable level, and the unit decibel (dB), to describe sound. Sound pressure level (SPL) is the logarithmic measure of the effective sound pressure of a sound. It is measured in decibels (dB) above a standard reference level. This logarithmic scale means that 3 dB is a doubling of the sound level however: 8-10 dB is double the loudness, which is defined as a psychophysical sensation perceived by the human auditory system. The quietest sound we can hear is 1 dB, and above 120 dB sound causes discomfort and even pain.

The scale is often adjusted to take account of the reduced sensitivity of human hearing to high and low frequencies and is then referred to as dB (A) or A-weighted decibels. There are also B-weighted and C-weighted scales, but the A-weighted scale is the one most commonly used for measuring loud noise. Sound is also described in terms of equivalent sound levels (Leq), measurements that address the average noise levels of fluctuating noises (Speaks, 1999). Another way of measuring sound is to identify the reverberation time (RT). RT measures energy decay and must be related to the volume and absorbency of a room. Larger spaces with less absorption have longer RTs (Hsu, Ryherd, Persson Waye, & Jeremy, 2012).

Hearing and listening

Intact hearing is crucial for us to be able to hear the sounds around us. Intact hearing provides an endless number of opportunities, such as taking part of in oral conversations and experiencing music, while a reduction in or lack of hearing can lead to limited access to information and as a result, exclusion (Kihlman, 1982). Muller (2012) suggests that four aspects explaining the importance of hearing can be identified. Firstly, hearing can be seen as "*a source of information*" (Muller, 2012, p 446), which means that the capacity of the ear enables us to hear countless sounds, thereby obtaining information that we would not otherwise have had access to, since some information can only be transmitted acoustically. Historically, conversation is the oldest form of communication. Moreover, the ability to perceive sounds starts early; unborn children are able to perceive sounds in the uterus. Sounds are also the first way in which the child communicates; crying is a way of attracting attention and expressing feelings.

Secondly, the ear's enormous capacity, which means that we can hear a tremendous amount of noise, also means that hearing can be used as a "*tool for orientation*". We use ambient sounds to orient in a room or the physical space we are in, but also in political, social and cultural spaces. All places have specific sound spheres. A third aspect is that when someone recognizes a specific soundscape, it provides them with an opportunity to "*gather experiences*". This means that people can act appropriately in both expected and unexpected situations. This is crucial when we hear sounds we associate with danger, for example, when a pedestrian hears the sound of a car approaching. Not hearing or being able to identify a sound in that situation could result in disaster. The fact that we use hearing to warn of danger is probably linked to our inability to close our ears in the same way we can close our eyes. We hear all the time, even when we sleep. This means that unexpected silence also can warn us of

danger. Finally, hearing is seen as a prime "*component of communication*". Hearing and speaking come before writing and reading, both from an individual perspective, children start to communicate orally long before they write, and also from a historical and societal perspective. Therefore, oral communication is an important part of human development (Müller, 2012).

Sound perception and interpretation

From a physical perspective, perception starts when the sound pressure reaches the eardrum and the eardrum starts to vibrate. The vibrations are transmitted through the middle and inner ear, activating tiny hair cells that pass the noise stimulation through the auditory nerve to the temporal lobe of the brain. The perceptions begin somewhere between the basilar membrane and the temporal lobe of the brain. The interpretation process is important since it helps us to understand the world. We perceive and interpret sounds via two parallel systems, consciously through the cortex (100 bits per second), and unconsciously via the limbic system (10 000 000 bits/s). Apparently, most perception is perceived unconsciously. Since the limbic system acts as an amplifier and helps us to respond to the sound before it reaches our awareness, we can rapidly and unconsciously react with pleasure or discomfort when we hear a sound. Past experiences are used, meaning that spaces and things are imagined without being seen using audio perception alone (Tham, 2001). Moreover, position in the place is of importance. A child and an adult in the same room experience sound differently of their difference in height. Similarly, someone lying down perceives sounds differently to someone standing up. Sound is also perceived purely physically, in that we feel sound waves differently (Zittoun, 2012).

Finally, the perception of sound varies with mood (happy-sad) and what we are currently doing. Thus, it is important to specify the perspective referred to when a certain sound or noise is discussed. Furthermore, an ability to distinguish sounds is required to handle all the surrounding sounds that hit us. We need to continuously identify them, distinguish them, name them and organize them. In all new places, there is a need to, in a relatively short time, distinguish between harmful and harmless sounds, important and unimportant sound. Once a sound has been "coded", we can go further and make a more detailed characterization of it, for example by identifying a specific bird or melody. Sounds are also linked to social and organizational structures as well as codes and history. We learn which sounds are acceptable in public settings and which are only acceptable in private; one example of this is bodily sounds.

Although our ability to interpret sound impressions is amazing, there are some limitations. Firstly, humans find it difficult to identify sound sources and, secondly, it is hard to distinguish between real and artificial sounds. This is something which can be seen as both an advantage and a disadvantage, one advantage is that engineers and designers can use this inability in films and theatres and today many people interpret new sounds based on their experiences of artificial sounds. For example, many people "know" what bombing sounds like without ever having experienced war. The downside is that there may be problems identifying the sound source making it hard for us to relate to it (Zittoun 2012). It is important to take this into account in critical illness where the patient' fatigue and unstable consciousness reinforces this problem.

Sound as a part of the place

Since our surroundings constantly express sounds in different forms and shapes, it is impossible to avoid becoming involved in sound. This means that all of us, young and old, healthy or sick need to relate to sounds daily in some way or another. Sounds are a part of the physical environment and acoustic ecologists describe this as "soundscapes", three-dimensional physical environments in which all living beings constantly move (Murray Schafer, 1977; Müller, 2012). Sounds are present in all rooms and places and, therefore, this thesis argues that sounds can be distinguished as a specific element with specific meaning. According to Zittoun (2012), the sounds around us possess the same characteristics as a "place", which means that they are pervasive. They are always experienced in some form, they constantly expose us to some kind of meaning and eventually, we are able to participate with sounds. Additionally, sounds order relationships we have with others and to the world in a deeper way. Based on these reflections, it is clear that he sounds that surround us interact with us and have a meaning for us when we are healthy. However, sound is both a physiological and subjective experience, which means that not all sounds are perceived as something positive. Therefore, the question remains: what sounds are perceived as valuable and useful and when does sound become noise, i.e. "*a sound that is loud or unpleasant or that causes disturbance*"? Are the sounds that surround the patient in hospital and in intensive care harmful to the patient? Kihlman (1982) describes sound as having several negative effects on humans: it can cause hearing impairment, interfere with conversations, disrupt sleep, cause negative psychological effects and impact on the vegetative nervous system. Already in 1931, the physicist G.W.C Kaye expressed that sound could be "*out of place" by its "excessive loudness, its composition, its persistency or frequency of occurrence, its unexpectedness, untimeliness or unfamiliarity, its redundancy, inappropriateness, or reasonableness, its suggestion of intimidation, arrogance, malice or thoughtlessness*" (Bijsterveld 2008, p 240). In the text section, a summary of research related to noise and its effect on human health is presented.

Noise and its effects on health

The most serious effect of noise is loss of hearing, which means that the cells in the inner ear die. Loss of hearing occurs when someone regularly, for a long time, is exposed to loud noise. The damage is irreversible and can only be partially be compensated by hearing aids (Kihlman, 1982). However, lower sound levels can also affect health. The negative health effects of noise in general (road, railway, aircraft) are described in several studies both in different areas and in humans and animals but will only be mentioned briefly here. A review by Seidman & Standring (2010) states that, even after one hundred years of research it is hard to quantify the non-auditory effects of noise as many studies have to deal with a number of confounding variables. Passchier-Vermeer & Passchier (2000) have, in a review, looked at studies concerning the effects of sounds generated by sources in the environment (indoors, outdoors, at work etc.) and concluded that exposure to noise constitutes a health risk. They mean that existing research in the area is sufficient to conclude that noise increases the risk of hypertension and heart disease. Moreover, noise can cause annoyance and sleep disturbance, which in turn can result in other adverse physiological effects.

Similar observations are described in a review by Hsu et al. (2012), who have compiled the epidemiology of noise pollution in hospitals in general, and who note, as mentioned above, that it is difficult to draw conclusions in the area. Some studies have methodological limitations and, moreover, there are few studies published on topics such as LoS, pain and wound healing and their their relationship to noise. However, some of the research available is presented in the following section.

Noise and its effects on sleep in the ICU

For most people, necessary fundamental needs such as sleep and rest are strongly linked to their surrounding environment. Hospitals, and especially ICUs, are not conducive to sleep and, therefore, the most commonly studied adverse effect of noise in hospital is sleep disturbance. Notably, a recent study stated that one night's sleep in healthy young men impairs the immune system visibly (Christoffersson et al., 2014). How poor sleep affects severely ill patients is still unknown but we do know that sleep is necessary for recovery and that sleep in patients in the ICU is inadequate.

Today, thanks to several studies which have identified sleep disturbances such as fragmented sleep patterns and an overrepresentation of Stage 1 and Stage 2 non-REM sleep in ICU patients, we know that most patients cared for in the ICU suffer from poor sleep. Furthermore, reduced or absent slow wave sleep and REM sleep are common (Aurell & Elmqvist, 1985; Freedman et al., 2001; Hilton, 1976). However, from a quantitative perspective, the cause of the problem is not fully understood because of to two factors. Firstly, in the ICU, many factors may affect sleep; staff-patient interventions (Celik et al., 2005), diagnostic procedures (Freedman et al., 2001; Freedman, Kotzer, & Schwab, 1999), medications (Cronin, Keifer, Davies, King, & Bixler, 2001), underlying disease procedures (Parthasarathy & Tobin, 2004), circadian pattern disturbances (Frisk, Olsson, Nylen, & Hahn, 2004) mechanical ventilation and noise are some of the factors which have been identified (Talwar, Liman, Greenberg, Feinsilver, & Vijayan, 2008). Additionally, unfortunately, several of these are difficult to estimate and measure. Secondly, there are several methods to assess sleep in ICU settings, which makes it difficult to compare different studies.

Nonetheless, sound and noise and their effect on sleep have frequently been studied and discussed over the years. In qualitative interview studies patients describe sudden arousals and awakenings because of voices in their room (Granberg, Bergbom Engberg, & Lundberg, 1998; Karlsson, Lindahl, & Bergbom, 2012; McKinley, Nagy, Stein-Parbury, Bramwell, & Hudson, 2002; Samuelson, 2011; Wang, Zhang, Li, & Wang, 2009). Moreover, in an observational study it was found that patients in an ICU reacted on average 35 times per day to noises in their room by, for example opening their eyes, moving their arms or legs etc. (Merilainen, Kyngas, & Ala-Kokko, 2010). In quantitative studies, there is still a disagreement concerning noise and its impact on sleep. A review by Xie, Kang, & Mills (2009) found that of 11 selected papers, 5 original papers suggested that noise is the most prominent cause of sleep disturbance while 6 suggested that noise is responsible for only a small proportion of the arousals and awakenings from sleep. However, since it is possible to influence noise, it is to be regarded as one of the most important factors regarding sleep.

Noise and physiological responses

Earlier studies performed in Coronary Care Units (CCUs) and ICUs describe links between high levels of noise and cardiovascular effects (Hsu et al., 2012). One study, investigating hospital noise levels in infant incubators, a recovery room and two rooms in an acute unit found a linear relationship between vasoconstriction and increasing sound levels >70 dB (A), and that high levels of so-called white noise (signals with similar hissing sounds), impacted vasoconstriction in a negative way (Falk & Woods, 1973). Altered heart rate and changed frequency of arrhythmias have also been found to be related to noise. In one study ventricular arrhythmias was seen at noise levels >55 dB (A) (Hsu et al., 2012) and, in another study, increased heart rate was seen if the noise level increased by 3 dB (a doubling of the sound level). This occurred regardless of the starting value (Baker, 1992). Noise from conversations and talking seems to influence the individual specifically; three studies found that patients' heart rate increased when someone was talking in the same room (Baker, 1992; Baker, Garvin, Kennedy, & Polivka, 1993; Marshall, 1972).

Gastric activity (Sonnenberg, Donga, Erckenbrecht, & Wienbeck, 1984; Tomei et al., 1994) and pain (Gardner, Licklider, & Weisz, 1960) are other areas which haves been studied concerning their relationship to sound and noise. Since these trials are small, more research is needed to be able to draw some general conclusions. Nevertheless, their preliminary findings indicate that noise has a negative impact in these areas. This also applies to noise and its effect on wound healing which, thus far, has primarily been studied in animals (Hsu et al., 2012).

ICU delirium

One condition that has troubled ICU health care professionals, researchers, patients and their families since the beginning of intensive care is something called *ICU delirium* or *ICU syndrome*. ICU delirium is a state of acute confusion and a change in cognition or perceptual disturbance that develops over a short period of time (Shehabi et al., 2010). The state lasts on average 2-4 days (Girard & Ely, 2008; Lin et al., 2004; Shehabi et al., 2010), and fluctuates over time (Granberg, Bergbom Engberg, & Lundberg, 1996; www.icudelirium.org, 2010). At worst, it can cause persistent disability. One study found that 70% of the ventilated patients with ICU delirium were cognitively impaired 12 months after being admitted to ICU (Girard et al., 2010).

ICU delirium can be categorized into two different states, hyperactive delirium, characterized by agitation, restlessness and emotional instability, and hypoactive delirium, characterized by apathy and responsiveness (Girard & Ely, 2008; Granberg-Axell, Bergbom, & Lundberg, 2001; Liptzin & Levkoff, 1992). Hypoactive delirium is the most common state and is seen in 60-65% of patients with ICU delirium (Pandharipande et al., 2007). Many qualitative studies have in recent years described this condition from the patients' point of view; narratives include unreal experiences, delusional memories as well as hallucinations and nightmares (Granberg et al., 1998; Granberg et al., 1999; Lof, Berggren, & Ahlstrom, 2008; McKinley et al., 2002; M. Ringdal et al., 2006; B. Roberts & Chaboyer, 2004; B. L. Roberts, Rickard, Rajbhandari, & Reynolds, 2006). In the mid-2000s, quantitative studies indicated a relationship between ICU delirium, a higher mortality rate and longer hospital stays.

Moreover, higher costs (Jonsson, Lindgren, Wimo, Jonsson, & Winblad, 1999; Milbrandt et al., 2004) and impaired quality of life (Ouimet, Kavanagh, Gottfried, & Skrobik, 2007) were detected. These results led to a change in approach and ICU delirium started to be taken seriously. Consequently, a lot of the research in recent years has been dedicated to exploring the mystery of ICU delirium. A search on Google in June 2014 for the phrase "ICU delirium" resulted in more than 25 000 hits, which means that there is considerable interest in the issue. The main cause of ICU delirium remains unknown, but it is probably an interaction between several components including physiological, psychological and environmental factors. Hitherto, most studies have focused on the medical aspects of ICU delirium and therefore most research is about physical variables. Those research findings show many medical risk factors (Arend & Christensen, 2009; Van Rompaey, Schuurmans, Shortridge-Baggett, Truijen, & Bossaert, 2008), but no direct cure. Similarly, today, the pharmacological treatment is focused on relieving symptoms. However, the recommended pharmacological treatment, haloperidol, and its effects have been discussed. Haloperidol has potential side effects such as prolongation of the QT interval and extra pyramidal effects and, moreover, there is a lack of randomized controlled trials (RCTs) in the area (S. F. Jones & Pisani, 2012).

In nursing literature, other risk factors such as psychological and existential factors have been identified. In one qualitative study, patients described how a constantly and long-term state of tension and fear and a loss of body control can develop ICU delirium (Granberg et al., 1998; Granberg et al., 1999). Patients described how they lost orientation, both in time and space, and how they used a lot of energy to regain control. Unreal experiences developed particularly at night, keeping the patients awake (Granberg et al., 1999). The consequences of the surrounding environment and its relationship to ICU delirium are poorly investigated, though there is growing interest in the issue. Some papers suggest that surroundings, and especially noise, play an important role and recommend so- called non-pharmacological preventions. However, these assumptions have not been scientifically confirmed (Baker, 1984; Barr et al., 2013a; Flaatten, 2007; Fraser & Riker, 2001; Jacobi et al., 2002; Pun & Ely, 2007; B. Roberts et al., 2005; Wenham & Pittard, 2009).

One recent comparative prospective study showed that the number of days with delirium decreased in patients who were cared for in a single-bed room compared to patients in a multiple- bed rooms in the ICU (Zaal et al., 2013), indicating that the sound environment is of importance. Another RCT study reported that using earplugs at night in the ICU lowered the incidence of confusion. Moreover, of the patients who did develop confusion, those who used earplugs developed confusion later than those who did not (Van Rompaey, Elseviers, Van Drom, Fromont, & Jorens, 2012).

Sound and noise in ICU - a literature review

It is well known that an ICU has a complex and demanding sound environment and, up to now, a lot of research has highlighted this problem. Sound levels and sound sources in the ICU have been studied in many countries and in different types of intensive care. Additionally, some studies have explored interventions for improving the sound environment. A literature review of the existing research in the field follows.

Sound pressure levels in the ICU

Numerous studies in recent years have explored and described the acoustic environment in a patient's room in the ICU (Konkani & Oakley, 2012). However, it is difficult to compare results and draw conclusions since there are major methodological differences between the studies.

The author have reviewed thirteen studies published between 1977 and 2013 presenting measurements from eighteen different ICUs in the UK, the USA, Austria, Greece, Turkey and Sweden in some detail (Table 1). These studies represent different kinds of ICUs (general, surgical, medical, pediatric, burn, neurological and thoracic) with varying room size (one-bed to eleven-bed rooms). In these studies, the median dB LAeq level of 58.3 (range 53-64) was found which is much higher than recommended levels (Table 2-4).

Sound sources

However, since the ICU's high-tech and high-activity environment does not consist of only one constant background noise it is important to mention the complexity of the sound sources (Park, Kohlrausch, de Bruijn, de Jager, & Simons, 2014; Tegnestedt et al., 2013). Sudden sounds constantly occur in the ICU patient room, therefore, the intervals between sound events are very short. Early on, Bentley et al. (1977) found a meantime of 1.5 minutes between loud noises (LAeq per 30 min >70 dB) during the day (06-24). At night, these intervals lasted for an average of nine minutes. This was later confirmed by Balogh et al. (1993) who found that even at night the longest quiet interval was only 22 minutes (LAeq 24 h). A later study from Sweden (Ryherd et al., 2008), identified *restorative* periods where LAeq was less than 50dB, LAFmax <55 dB or LCPeak <75 dB for 5 minutes or longer. When five 24-hour periods were investigated, mean restorative lengths (LAeq <50 dBA (1 min intervals)) were found to be 9 minutes during the day and 13 minutes at night. On one of the days (7 a.m-9 p.m.), only five such restorative periods occurred.

Where do all these sounds come from? Some studies have identified and quantified the sources of sound and their sound levels in the ICU patient room. MacKenzie & Galbrun (2007) who investigated two ICUs and one High Dependency Unit (HDU) in the UK found 86 (!) different noise sources. Bailey & Timmons (2005) found 41 and Akansel & Kaymakci (2008) found 31. One important source of sound is the technical equipment. Examples mentioned in studies include the monitoring system (Akansel & Kaymakci, 2008; Bailey & Timmons, 2005; Balogh et al., 1993; Lawson et al., 2010), the ventilator (Bailey & Timmons, 2005; Lawson et al., 2010; Tsiou et al., 1998), noninvasive ventilation (Cavaliere et al., 2004), suction tubes (Jang, Song, Kim, & Wang, 2004), infusion pumps (Akansel & Kaymakci, 2008; Bailey & Timmons, 2005; Lawson et al., 2010) and the hemofiltration machine. Balogh et al. (1993) found that an average of 2.1 alarms/ hour/ patient was registered but it was not unusual for more to occur. For one patient in a critical condition 42 alarms/ hour were observed. Nevertheless, even if the machines in the ICU are expected to be noisy it is clear that staff are involved in most of the noise, either directly or indirectly. Some believe that fifty percent of the sound peaks in hospital are attributable to human

Table 1. A short description of 18 acoustic studies performed in ICUs and presented in 13 published papers between 1977 and 2013

Author/Hospital	Country	Published Year	Type of ICU	Number of measure-ments	Number of beds	Place of microphone	Time of measurment	LAeq dB
Bentley	UK	1977	General	5days	*	*	30 min intervals/24 h	53
Balogh	Austria	1993	General	2days	4	Middle of the room	20min	63
McLaughlin	UK	1996	Surgical	1day	*	*	1 min intervals/16h	57,5
Moore	USA	1998	Thoacic	3days	*	Middle of the room	1 min intervals/24h	61,8
Tsiou	Greece	1998	General	9days	6	Middle of the room	8h	67,4
Cmiel	USA	2004	Surgical	1day	2	Middle of the room	9h	53
Bailey &Timmons	UK	2005	Pediatric	3days	3	Middle of the room	5 min intervals/24h	61,2
Mackenzie & Galbrun/ WGH	UK	2007	General	1day	6	Above the patient's head	1 min intervals/24h	54,9
MacKenzie & Galbrun /ERI	UK	2007	General	1day	8	Above the patient's head	1 min intervals 24h	57,8
Christensen	UK	2007	General	3days	9	Middle of the room	5 min intervals/72h	56,4
Ryherd & Persson Waye	Sweden	2008	Neurological	5days	2	Above the patient's head	1 min intervals/120h	57
Akansel	Turkey	2008	Surgical	35days	11	Above the patient's head	15 min intervals/24h	64
Cordova	USA	2013	Burn	6days	1	Above the patient's head	30 min intervals/24h	65
Darbyshire/ John RH	UK	2013	General	1day	*	Above the patient's head	1 min intervals/24h	59,7
Darbyshire/ Churchill H	UK	2013	Surgical	1day	*	Above the patient's head	1 min intervals/24h	55,4
Darbyshire/ John R NICU	UK	2013	Neurological	1day	*	Above the patient's head	1 min intervals/24h	58,8
Darbyshire/ Berkshire	UK	2013	General	1day	*	Above the patient's head	1 min intervals/24h	59,9
Darbyshire/ Wycombe	UK	2013	General	1day	*	Above the patient's head	1 min intervals/24h	55,4

*Data not available

behavior (Choiniere, 2010). Talking, including conversations among ICU staff was the most common and generated approximately LAeq 24 h of 74 dB (Akansel & Kaymakci, 2008) and LAeq 8h 75-81 dB (Tsiou et al., 1998). MacKenzie & Galbrun (2007) found that talking occurred as much as 12% of the time. This means that staff are in a key position to influence.

Patients memories of sounds and noise in the ICU

In recent decades, there have been no studies directly examining patients' recalls or experiences of the acoustic environment in their room in the ICU. However, many studies with other research questions have touched on the subject. For example, several quantitative studies examining patients' stressful experiences from the ICU report that approximately half of the patients recall surrounding noise as disturbing or stressful (Hofhuis et al., 2008; Rose et al., 2014; Rotondi et al., 2002). This has been confirmed by qualitative interview studies in which noise sources are described more in detail. Interviewees described their surrounding environment as extremely disorganized and demanding, never really quiet or peaceful, which caused a kind of overload (Johnson, St John, & Moyle, 2006; Lof et al., 2006). One example of disturbance was loud conversations between staff inside the patient's room which was experienced as both annoying and bothersome by many patients (Granja et al., 2005; Hofhuis et al., 2008; Merilainen, Kyngas, & Ala-Kokko, 2013; Samuelson, 2011; Wang et al., 2009). At worst, the loud voices from staff caused the patient to feel that no improvement was being made which, in turn, led to fatigue and dejection (Hofhuis et al., 2008; Johnson et al., 2006). Another problem mentioned in some studies was noisy patients in the same room; screaming, agitated patients or patients needing special treatment or resuscitation. Hearing these noises could increase the feeling of fear and insecurity as well as impair sleep quality (Granberg et al., 1998; Merilainen et al., 2013; Samuelson, 2011). Finally, unfamiliar noise from technical equipment could be experienced as both irritating and frightening (Almerud, Alapack, Fridlund, & Ekebergh, 2007; E Gjengedal, 1994; Samuelson, 2011). Sound may trigger memories years after discharge; a patient in a Norwegian study describes ten years after the hospital stay that "*I do not actually remember the sound, but it is something about it!*" (Storli, Lindseth et al. 2008 p 91).

Interventions designed to improve the sound environment

In recent years, several studies describing interventions to improve the sound environment have been published. How the interventions were designed varies as do the sound enhancing measures. Some examples include adjusting alarm settings (Dube et al., 2008; Kahn et al., 1998; Walder, Francioli, Meyer, Lancon, & Romand, 2000), reducing noise from conversations (Dube et al., 2008; Kahn et al., 1998; Taylor-Ford, Catlin, LaPlante, & Weinke, 2008), keeping doors closed (Dube et al., 2008; Lawson et al., 2010; Li, Wang, Vivienne Wu, Liang, & Tung, 2011; Moore et al., 1998; Taylor-Ford et al., 2008; Walder et al., 2000), coordinating care activities (Walder et al., 2000) providing earplugs (Richardson, Allsop, Coghill, & Turnock, 2007), lowering the sound levels of the alarms (Li et al., 2011) and dimming lights (Dube et al., 2008; Li et al., 2011; Walder et al., 2000). All of these have proven to be effective ways of improving the sound environment in a patient's room, both in the ICU and in other settings. However, there have been no long-term follow-ups of these interventions.

Existing facility guidelines

In Sweden there are no specific national guidelines regarding the acoustic environment in ICU patient rooms. What we do have are guidelines from the Swedish Standards Institute (SIS) that say that the sound level in an indoor environment intended for individual work, conversations or rest should be 35 dB with a LAFmax level of 50 dB (SIS/TK 197, 2007).

Moreover, there is a parliamentary resolution on noise limits associated with the construction of new infrastructure, i.e. guideline values not to be exceeded in housing constructions or when modifying traffic infrastructure (Proposition 1996/97:53, Infrastrukturinriktning för framtida transporter) (Table 2).

Table 2. Recommended sound levels according to Proposition 1996/97:53

Indoor LAeq	30 dB
Indoor at night LAFmax	45 dB
Outdoors (at the front) LAeq	55 dB
On the patio adjacent to the property LAFmax	70 dB

The Swedish Work Environment Authority (SWEA) (Arbetsmiljöverket) has drawn up regulations for activities for anyone exposed to noise at work (Table 3).

Table 3. Upper threshold values in terms of risk of hearing damage

	Threshold value
Daily noise exposure* level L_{ex}, 8h [dB]	85
Maximum A-weighted sound pressure level LAFmax [dB]	115

* Daily noise exposure level L_{ex}, 8h = Equivalent A-weighted sound pressure level normalized to an eight-hour workday. Includes all noise on work, including impulsive noise.

The only existing international guidelines available concerning noise in general are relatively old and not designed for high tech environments or critically ill patients. Below, Table 4 shows the current existing recommended sound levels for indoor environments, the World Health Organization (WHO) guidelines for community noise and the recommendations from the Environmental Protection Agency (EPA).

The WHO guidelines for community noise were formulated in 1999 by an expert group chaired by Birgitta Berglund, Thomas Lindwall and Dietrich H Schwela (WHO, 1999). The aim was to provide guidance and assistance to environmental health authorities and others who work with sound and noise issues and to protect people from the harmful effects of noise in non-industrial environments. The recommended levels below concern “most spaces in hospitals”.

The Environmental Protection Agency (EPA) is a U.S.A commission responsible for publishing scientific information to the public regarding the effects of sound and noise. It is also required to draw up limits to protect public health and welfare under various conditions. The recommended levels below apply to indoor environments in general, not specifically to hospitals (EPA 550/9-74-004 1974).

Table 4. Noise level limits (dB LAeq) for day and night, recommended by WHO and EPA

	WHO (dB LAeq)*	EPA (dB LAeq)**
Day	35	45
Night	30	35

* Most spaces in hospitals ** indoor environments in general

Care environment

Central to this thesis is sound, which is an important part of the care environment as sound can be not only caring but also uncaring and even harmful to the patient. Sound has not been discussed specifically to any great extent in the caring sciences but the concept of environment has. There are many ways of looking at the environment, the place, space and the room depending on the current perspective and, therefore, some reflections concerning the environment in general are discussed in the following section.

Environment - general reflections

Our surroundings, what is called the environment, are essential for all human beings. Some concrete examples of our surroundings are the air we breathe, the sounds that help us to communicate and the people we encounter daily. Every day, humans move through different environments and using their senses they record messages and information from those environments including the type of environment, how it is meant to be used and how he/ she is expected to behave in it. How one interprets and perceives the present environment depends on one's personality, past experiences and the current situation, as well as where one is heading at that moment. Depending on present conditions and personality, the environment is registered as different parts, i.e. only details that are of interest or as a whole (Fridell, 1998). As a concept the environment includes a lot of components, but a brief simplified definition, as described in nursing science literature, could be all the external and internal conditions that affect human development in some way (Olausson, 2014; Ylikangas, 2002). The word milieu (in Swedish, *miljö*) is derived from the French language and means centrality (in Swedish, *mitt*). From a caring science perspective, Ylikangas (2002) carried out a semantic concept analysis of the word milieu and found, seen from a historical perspective, that the approach to the word has been changed. It has gone from a relatively reductive concept to a more holistic form in which the human being is seen a part of a larger context. From meaning, just over 100 years ago, center (in Swedish, *medelpunkt*) or middle (in Swedish, *medelväg or mitt*), it has evolved into meaning something more descriptive with synonyms like atmosphere/ambience (in Swedish, *atmosfär*), sur-

roundings (in Swedish, *omgivning*) and relationship (in Swedish, *förhållande*). In recent years, it has expanded to include circuit (in Swedish, *krets*), nature (in Swedish, *natur*) and world (in Swedish, *värld*). Within the conceptual models and theories developed within the nursing sciences, the view of what the concept of environment includes has been discussed in various ways, and the discussion's development follows the same pattern as that of the semantic development. Early theorists had a relatively narrow perspective while later theorists take a broader and more abstract approach.

Early theorists, like Nightingale, Peplau, and Orlando, defined the environment as; "*all things external to nurses and their practices*" (Andrews & Moon, 2005, p 143), while later theorists, like Bates, Levine, Patterson and Zderad, have analyzed the environment as "*an exchange and interaction between internal and external elements*" (Andrews, 2005 p 143). For example, from the 1980s onwards, like in King's, Roy's, Parse's and Fitzpatrick's theories, the environment is taken to be "*an inseparable interrelationship of internal and external elements* "(Andrews, 2005, p 143). Here, it may be of interest to note that Florence Nightingale is the only theorist who discusses noise specifically as a significant factor influencing health and wellbeing. However, in summary, central to these theories and philosophies is the notion that the surrounding environment affects us and interacts with us, meaning that no one is unaffected by what is going on in the rooms they are in.

In our environment, there are also a variety of places or spaces. The concepts of space and place are often used synonymously; thus, depending on the theoretical perspective, the meaning of the concepts differ (Olausson 2014). From a nursing and caring science perspective, the room or the space can be defined as something tangible and concrete and include the physical environment. It can also mean the inner room of a person. Lassenius (2005) describes how the meaning of the word room (in Swedish, *rum*) differs between Swedish and English, even though they originate from the same word. In Swedish, the word *rum* is associated with place (*plats*), locus (*lokal*) and space (*rymd*). In English dictionaries the word room, in general, means the physical space. Furthermore, Lasseinus (2005) describes, from a caring science perspective, an objective space, consisting of quantifiable, observable elements, and a subjective space, formed by human experiences, personal values and interaction with the surroundings. Moreover, Martinsen (2006) stresses that we move through places both in time and space; "*man is a part of the place, which is something constant, at the same time as man is moveable and mobile*" (p 21). She talks about the place as a house, containing meaning and belonging. She uses metaphors from acoustics and describes how a house "sings", and how the song of the house sets the tone for the social interactions in the place.

Other disciplines interested in places and spaces are health geography and nursing geography. These scientific perspectives focus on the physical environment and its impact on health and, thus, the place is seen as an integral element in the relationships between location, people and health care. Andrews & Moon (2005) and Carolan, Andrews, & Hodnett (2006) argue that both health and social experiences of illness and life events are influenced by space and place, but also that health affects the place. In sociology, place and space are key concepts, and place is considered to be the bearer of social and hierarchical structures that affect social patterns. Furthermore, the

concept of place is seen as a value loaded term including tensions in different forms reflecting power and status (Olausson, 2014).

Patient's views on the care environment

The caring relationship is the term most mentioned when patients are asked about the care environment and its impact. Patients want a patient-friendly atmosphere when admitted to hospital, and state that it is more about a feeling, what the place is like to be in, than its physically appearance (Douglas & Douglas, 2004). In one study, a patient expresses that "*it's the people that make the environment good or bad*" (Shatell, 2005, p 161). However, there are examples of components in the physical environment that have significance. Privacy is one such important factor (Engstrom, Nystrom, Sundelin, & Rattray, 2013). In one study, a patient mentions the noises from other patients in the room as disturbing and argues that the sound impressions drained him of energy and provoked thoughts on his own existence (Shattell, Hogan, & Thomas, 2005). It is import to note, however, the more vulnerability and fear experienced by the patient, the greater need for staff presence; feeling secure and safe is generally considered more important than privacy. Another important factor is control; a good environment is defined as an environment that provides the individual with control, such as being able to move freely within the department, creating privacy by using doors and curtains, being able to control sound and light and to open the window (Douglas & Douglas, 2004).

The intensive care environment

The ICU is a complex area. Usually it is inaccessible and away from the public eye, which means that only a few have access. Intensive care is defined as the advanced monitoring, diagnosis and treatment of impending or manifest failure of vital functions. Intensive care is one of the most advanced forms of health care and the ICU is the place in the hospital where the most seriously ill patients are cared for by specially trained staff. Moreover, it is typically a specially designated section of a hospital containing the equipment, medical and nursing staff and monitoring devices necessary to provide intensive care. Its goal is to prevent and treat failure in vital organs, help patients through a life-threatening crisis and assist in their recovery so that they can return to the lives they led prior to a traumatic event. In 2008, there were 88 ICUs in Sweden, 69 of them were mixed ICUs while the others were specialized units such as cardiothoracic, neuro, pediatric and infection ICUs. In a mixed ICU, patients with various diagnoses and injuries are treated. A patient's mean stay is rather short; in Swedish ICUs it is approximately 3 days. However, there are considerable variations; some patients only stay for a few hours while others need care for several months. Sepsis, respiratory insufficiency and gastro intestinal bleeding are the most common diagnoses. Approximately 60% of patients are men and ca 14% are over the age of 80 (SIR, 2014).

The ICU patient room - a physical perspective

Figure 2 is a photo from an ICU patient room in Sweden. This room is representative for ICUs built in Sweden in the 1980s or 1990s. The architectural focus at that time was on the patients' physical needs, hygiene aspects and the needs of the staff. In this

room, the window is positioned behind the patient meaning that the patient can never look out of the window. The patient is situated in the middle of the room surrounded by monitors, infusion pumps, equipment and a ventilator. Occasionally, other space-consuming and loud machines, such as a continuous dialysis machine, extracorporeal membrane oxygenation (ECMO) and intra-aortic balloon pump (IABP) are needed in the room. There is a washbasin in the room and, usually a desk with a computer. In Sweden, two-bed or three-bed rooms are common, which means that the beds are separated by thin fabric curtains or mobile walls. The rooms are small and, as can be seen, there is not much space left for the patient's family. The team treating the patient is comprised of several professions. The physician, usually an anesthesiologist, has the medical responsibility and makes decisions about medical treatment and procedures. He/she is not stationed in the patient's room, but is available around the clock. The ICU nurse's main responsibility is to provide and coordinate care that has been individually adapted for the patient. However, tasks like monitoring and documenting vital signs, administering drugs, identifying and treating pain and monitoring fluid balance are included in the ICU nurse's duties, as are monitoring and managing various treatments such as ventilator- and dialysis therapy. The ICU nurse is stationed in the patient's room together with the enrolled nurse. The staff to patient ratio in Sweden is typically 1:1 or 1:2, and the practice is to never leave the patient alone in the room. The team also includes physiotherapists whose daily task is to maintain patient strength and abilities and prevent and treat any complications caused by lack of mobility and loss of physical condition. Finally, the room is cleaned by specially trained personal every day.

Figure 2. Picture from a two-bed ICU patient room in a Swedish hospital opened 1996.

In Sweden, an additional year of advanced studies at a Master's degree level (a one year post graduate university education) is required to work as a critical care specialist nurse. The program includes a variety of areas ranging from identifying and addressing acute physical needs to meeting needs of an emotional or existential character.

The ICU patient room - a patient perspective

From a caring science perspective, the complex ICU environment and its interaction with the patient have been discussed for some time. When a patient is admitted to hospital and the ICU, it is a meeting with a totally unfamiliar world. Most often, the reason for admission is a life-threatening condition in which the outcome is uncertain. Additionally, the illness has often progressed for several days resulting in gradually declined energy levels. Evidently, the patients have not only left their family and well-known surroundings, but also lost their privacy. Their ability to record impressions is changed; they are in a lying position, fatigue limits their field of vision and impairs their hearing. Moreover, their ability to move is limited because of the lines that connect them to infusions and technical equipment and, thus, their process of interpretation becomes affected (Fredriksen & Ringsberg, 2007). This, in turn, affects their feelings of control and power. Furthermore, sounds come from different directions, people move to and fro, talking incessantly (Samuelson, 2011) making it hard to identify the different sources. The staff never leave the room and it is never quiet. Consequently, the patient has very little influence on the physical room and activity (Engstrom et al., 2013). Moreover, there is an unwritten law that the staff have the right to enter the patient's space, but not vice versa.

As a result, critically ill patients find themselves in a situation where their environment is more or less out of control (Bergbom, 2014). This means that there is an asymmetry between the patient and the staff concerning control of the physical patient room (McMahon, 1994). If the environment is perceived as frightening and difficult to understand, it is experienced as a breach of existence (Olausson, Lindahl, & Ekebergh, 2013). At worst, the patient refrains completely from processing impressions; he/she becomes pacified and let others interpret the world instead. This complicates the patient's connection with reality and reduces their ability to regain a normal life (Fridell, 1998). This is to be compared with what Baker (1984) referred to earlier, called "sensory overload", characterized by a marked increase of stimuli, i.e. above a normal level. In the ICU, an overexposure to light, sounds and staff activity is common. Sensory overload leads to a deteriorated processing of information and thus, impressions lose their meaning.

Furthermore, Olausson et al. (2013) have, from a phenomenological perspective, investigated patients' meanings of the ICU patient room as a place of care and found that a struggle for life characterized the room. In this struggle, the interior design and personal belongings could be experienced as both a support towards recovery and a source of power. The experience of the room was connected to the patient's physical condition; pain and reduced vision influenced spatial perception, which meant that the shape of the room changed continuously. Some patients found themselves to be in a place "in-between" dream and reality, a condition that affected their perception of

the room; "*fittings and equipment are transformed as well as the place itself*" (p 239). However, the room could also be seen as a room of possibilities, trust and security, a place where the patient's life was rescued and assisted to a meaningful life. The interaction with staff was considered invaluable and the caring acts created confidence in caregivers and the family. The ambient sounds were also experienced as important, they became a natural part of life and gave structure to the room.

THEORETICAL PERSPECTIVE

Critically ill or injured patients who need care in the ICU are often tired and under the influence of sedative drugs; in the worst case they are unconscious. In such a vulnerable condition, the care they receive, how it is performed and how their needs are responded to, are of specific importance. Being ill and depending on others for basic needs create vulnerability, together they may become a threat to human dignity. Being surrounded by a good, calm physical environment when critically ill should be considered an important basic prerequisite, as it promotes rest, sleep and wellbeing. Moreover, a calm environment provides security, a factor that promotes recovery and health. Therefore, this thesis argues that good professional care includes responsibility for the physical environment in the ICU, since it is believed that the patient's surroundings interact with the body, mind and spirit and, accordingly, have an impact on the patient's health and wellbeing.

Being a patient in the ICU

Since the caregiver's view of the patient is crucial for how caring is expressed and performed, it is important to elucidate the concept of a patient from historical and caring science perspectives. In the caring sciences, the word patient is used to define someone who is cared for (Kasén, 2012). The word *patient* is derived from the Latin verb *pati* (to suffer), and the noun *patient* (meaning suffering) (The Oxford dictionary 2014), but it has had different meanings in the Swedish language throughout the years. Konvalescent (in English: *convalescent*), sjukling (in English: *invalid*), skyddsling (in English: *protégé*), klient (in English: *client*), fall (in English: *case)* and kund (in English: *customer*) are some of the words synonyms for the word patient in Swedish dictionaries between 1853 and 1999, (Kasén, 2012). The meaning of the word patient has been discussed, particularly in the philosophy of caring. Arman & Rehnsfeldt (2006) describe how the concept of a patient may have two meanings for professional caregivers. On the one hand, it can mean someone who needs care; that is, someone who needs help or support and, therefore, the person is allowed to simply be patient. On the other hand, the concept of a patient can be seen as a universal and egalitarian phenomenon where the professional caregiver becomes aware of his or her own vulnerability. In that meeting, the caregiver and the patient meet in reciprocity as people (Arman & Rehnsfeldt, 2006). These two meanings can be observed in intensive care where severely injured and critically ill patients are cared for.

However, complex intensive care requires that the approach to the patient be further clarified. As mentioned earlier, patients cared for in the ICU are not a homogenous group, rather the opposite. Their need for help and support varies widely both as a group of patients but also as individuals during their stay in an ICU. Some patients are to be seen as completely vulnerable, unable to express or meet their own needs or desires, while others are fully aware and should be involved in and seen as partners in their care. This places great demands on the ICU staff who must continually adapt their approach and caring to the individual patient and his or her resources. These differences can also complicate the ability to create caring environments and caring soundscapes since sound is a subjective experience and perceived differently.

Caring

The purpose of caring is to meet sick people's needs, relieve their suffering and promote their health. Therefore, it is of interest to ensure that the environment in which the patient is cared for does not harm them, but is conducive to their health. The word care is derived from the Latin word *caritas* meaning love, which indicates that the word care encompasses more than a "cure" and medical treatment (Eriksson, 1991). Caring in various forms, as a natural part of human relationships, has been performed throughout time and in all cultures, involving the care of children, elderly and sick people. However, in parallel with natural care, professional care has been performed and, thus, historically, it has been attributed to the medical field (Söderlund, 2012). Caring, which is the essence of care and nursing, has been of interest to many over the years and, as a phenomenon, it has been studied and developed. In nursing philosophies and theories, caring has been described in different ways- caring as a moral imperative, caring as a therapeutic or interpersonal intervention are some of the identified approaches (J. M. Morse, Solberg, Neander, Bottorff, & Johnson, 1990). In intensive care, where the nurse is expected to measure, record and manage a lot of equipment, there is a risk that the patient does not receive enough attention. It is quite possible to be physically present but mentally absent; that is, with one's mind on a totally different subject (Ashworth, 1990).

However, good and adequate caring requires total presence. Only then is it possible to identify needs other than medical. The care delivered must take account of the whole person (Tomey & Alligood, 2006). Genuine caring is about commitment, including respect for and an approach toward the patient as being a unique and valuable human being. It is a way of living, not a behavior or a state of being. According to Eriksson (1987) a human being constitutes an entity composed of body, soul and spirit. Eriksson (1987) argues that caring is an expression of reciprocity and an interactive process, and that it is not only an act but a way of being and living and, based on this approach, caring acts, the most primary form of care, are expressed. Put simply, it is the art of making something significant out of something seemingly less important. True care is not a form of behavior, nor a feeling or state, it is being there. Lassenius (2014) expresses this as "c*are takes place between people, while caring is experienced within man*" (p 25). The act of caring can also be viewed as an aesthetic experience or as art in the sense that it is about doing good and making the world a better place. Obviously, an aesthetic care has a goal and a purpose (Eriksson, 1991). Its focus is the way caring is carried out, the spirit in which it is done (Eriksson, 1987).

In an area where, historically, medically oriented measures have had higher status, it can be difficult to highlight issues affecting basic needs. Söderlund (2012) describes caring as the struggle to alleviate suffering and protect the individual's dignity. Consequently, caritative care implies activity that takes responsibility for and aims to preserve and restore someone's sense of dignity when he or she is incapable of doing so on their own. It is not something that comes by itself; it is not easy, and it requires hard work. Firstly, courage is required to stand up for what is good and to make moral decisions that result in alleviating suffering since caring is seen as a virtue and an ethical act (Levy-Malmberg, Eriksson, & Lindholm, 2008). Secondly, it requires a strategic plan, skills and the ability to be present in the here and now (Söderlund, 2012). Ad-

ditionally, being cared for in a hospital also means being in a context where relationships are asymmetrical; the care professionals inevitably retain a power advantage (Sellman, 2005; Sivonen & Kase´n, 2003).

Primarily, caring means guiding a person, not formulating the goals. However, situations may arise when a person is unable to set his or her own goals; then, it is the caregivers' responsibility to take over. It is a mission that requires the ability to understand the other person's desires and needs. Thus, the respect for man and life must guide the caring act (Eriksson, 1991). In the ICU, most patients are not able to set their own goals or decide on what they should prioritize; caring for critically ill patients in the ICU is a challenge and a responsibility. Illness and fatigue place the patient in a particularly vulnerable and distressful situation where caregivers must take responsibility for areas normally handled by the patient him or herself, including creating a good healing environment.

Suffering

Another central concept in nursing philosophies is that of suffering, which is seen as a basic category of caring (Arman, 2012; Eriksson, 1993; Tomey & Alligood, 2006). The word patient derives from the Latin word *patient* meaning "the one who endures or suffers" (Eriksson, 2001). Moreover, the word compassion comes from the word sympathy derived from the Greek word *sympateia* which means "to suffer with". Concretely, caring means to have compassion since compassion is the source of true caring (Eriksson & Herberts, 1993). Thus, alleviating suffering is the core of caring. Caring means daring to be involved, to face suffering and to target suffering as suffering. It is not possible to eliminate suffering; caring is to make suffering bearable. Suffering is defined as an ongoing battle between good and evil which is expressed by aspects and characteristics such as physical, mental, spiritual and social suffering. Moreover, suffering is considered as an inevitable part of life but lacks definition or reason (Arman, 2012).

Suffering caused by care

Unfortunately, not all care is caring. Lindholm & Eriksson (1993) has developed a concept called care suffering (suffering caused by care). This is a suffering which is not directly related to illness or injury; rather, it can be completely independent of it. Care suffering is the result of insufficient care, absence of care or "over" care. Moreover, caregivers' inability to recognize patients' needs, resulting in violation of patients' dignity, results in care suffering in that it reduces man's ability to be human and use his/her inner health resources. Being subjected to the exercise of power may result in care suffering in that it forces the patient to act in a way he or she cannot manage. Furthermore, being taken seriously or be excluded is a way of exercising power over the powerless (Arman & Rehnsfeldt, 2006; Eriksson, 1994). Olausson et al. (2013) put this in a clinical context when they described how non- caring acts also affect the experience of the ICU environment. When the needs of the critically ill patients are not catered for, the ICU room is perceived as frightening and impossible to live in. Whether the noise in the ICU patient room causes care suffering has not previ-

ously been studied, but this thesis argues that it is in the interest of the caring science to further explore whether this is the case.

Vulnerability

Another term that is closely connected to the word suffering is the word vulnerability. Historically, as a concept, it has not been used in nursing theories and nursing philosophy to the same extent as the words caring and suffering. According to Wadensten (2005), who analyzed ten nursing theorists concerning the concept, only Orlando and Wiedenbach have used the word specifically. However, it is implicit in the other theories analyzed, in that they all believe that that patients who are in need of care are vulnerable. In nursing philosophy, the concept has, among others, interested Kari Martinsen, a Norwegian philosopher who delved into the topic in her book 'Care and Vulnerability', where she discusses the challenge of caring for the vulnerable and frightened patient's body (Martinsen, 2006). Furthermore, more recently, vulnerability has been discussed within nursing philosophy, where the common position is that all human beings are basically vulnerable, "*an existential phenomenon*" (E. Gjengedal et al., 2013, p 136), which makes us fragile (E. Gjengedal et al., 2013; Sellman, 2005, 2009). Daniel (1998) expresses that, "*a human being who is invulnerable is inhuman*". However, although we, as healthy humans, are vulnerable, there is consensus that sick people are more vulnerable than others in that they lack the ability to protect themselves from harm. The more serious their condition, the less ability they have to control the situation. This means that patients in the ICU are particularly exposed.

Furthermore, Sellman (2005) emphasizes that it is important not only to express that someone is vulnerable, the "vulnerable child" or "the vulnerable ICU patient", it is also important to clarify what these patients or groups are vulnerable to. In this thesis, it is argued that patients in the ICU are vulnerable to a non-caring environment, which includes unwanted sounds. Other aspects that have been discussed in the literature are subjective and objective vulnerability respectively (Carel, 2009; Sellman, 2005). Objective vulnerability might be more evident, but since no one knows how to react in cases of illness or injury, it is important to note that there is not necessarily a relationship between illness and feelings of subjective vulnerability (Gjengedal, 2013). Evidently, vulnerability is "*a contextual phenomenon*" (Gjengedal, 2013, p 136), since the degree of vulnerability will vary depending on the situation and the context. How vulnerability is experienced also varies; it is strongly connected to how we are met when we are vulnerable. Therefore, Gjengedal (2013) also states that vulnerability is to be seen as "a *relational phenomenon*". She refers to Levinas when she says that vulnerability is the foundation of ethics; that is, only by being open and receptive towards someone else's vulnerability, can we act and care ethically. To try to understand the critically ill person's lived world is necessary for meeting their needs and making their situation bearable, at best, transforming their experience to strength.

RATIONALE FOR THE STUDY

Previous research has shown that sound pressure levels in the ICU patient room are high and that the sources of sound are many, but how critically ill and vulnerable patients being cared for in the room experience the sound environment has not previously been studied. Critically ill patients are particularly fragile and vulnerable and cannot control environmental factors such as sound and circadian rhythms. Therefore, staff and the health care organization are obligated to meet these needs. Studies have shown that noise levels in hospitals have increased in recent years, suggesting that insufficient or no measures have been taken to solve the problem. In order to create a good, curative and caring environment around the patient, a greater understanding is required of how severely ill patients experience and manage the sounds that surround them. Furthermore, knowledge of sound and its effects on the health of those who work closely with the patient is needed, and, currently, there is a lack of surveys regarding staffs' basic knowledge of sound and noise.

Previous studies in other sciences have shown that sound and noise, directly or indirectly impact health negatively; sleep disturbance and cardiovascular response are some examples mentioned in the literature. However, how sound and noise influence critically ill patients is currently unknown, and only a few randomized clinical intervention studies have been done in the field. Conducting complex clinical intervention studies in the context of critical care is a challenge and, therefore, careful preparation is required before the start. A detailed description of the challenges and issues that must be considered can be helpful for other researchers planning randomized clinical trials in intensive care.

The results of this thesis can contribute to increased knowledge about the phenomenon of sound and noise in the ICU patient room and increase the understanding of what it is to be cared for in a complex acoustic environment. This knowledge is important in the development of professional caring in intensive care. Furthermore, an inventory of knowledge can be used not only as a basis in educational interventions, but also in clinical staff trainings. Finally, many hospitals in Sweden and the western world are about to construct new buildings or renovate existing ones, which means that knowledge of sound and noise and their effects is highly relevant.

AIM

Overall aim

The aim of this thesis was to illuminate how critically ill patients experience being surrounded by sound and noise. Furthermore, it also aimed to explore ICU staff's knowledge and suggestions for improvements regarding this sound environment as well as investigate the feasibility of a complex sound intervention in an intensive care context.

Specific aims

Study I: To describe, using a quantitative approach, the noise environment in an ICU patient room during one day, a patient's physical status during the same day and early signs of ICU delirium; second, to describe, using a qualitative approach, patients' recall of the noise environment in an ICU patient room.

Study II: To illuminate the meanings of being critically ill in a sound-intense ICU patient room, as disclosed through patients' narratives.

Study III: To investigate physicians', nurses' and enrolled nurses' knowledge concerning sound and noise in the ICU: and, identify the staff's own suggestions for improving the sound environment in the ICU patient room.

Study IV: To explore, if it is possible to implement a full-scale intervention study in an ICU concerning sound levels and their impact on the development of ICU delirium. A second purpose was to discuss methodological challenges and explore solutions for the forthcoming study.

METHODS

Methodological considerations

Sound is a unique phenomenon; it can be measured and quantified, but it is also experienced subjectively. Therefore, it was important to elucidate the topic from multiple perspectives. In this thesis, studies with different focuses and approaches are represented. In Studies I, III and IV, a logical empirical tradition has been used where the focus has been, using measurable observations and logic, to quantify data and searching for relationships between variables. Furthermore, in Studies I, II and III, a humanistic science tradition of understanding and interpretation has been used.

Content analysis

Content analysis is an empirical grounded scientific method that can be used both with a quantitative and qualitative approach. The essential aim of content analysis is to develop knowledge, create new insights and give the researcher new understanding concerning a specific phenomenon (Krippendorff, 2004; Sandelowski, 2000). Moreover, content analysis should be objective and systematic (Berelson, 1952). Therefore, it is not connected to any specific theory and several have described and developed the method (S. Elo & Kyngäs, 2008; Graneheim & Lundman, 2004; Hsieh & Shannon, 2005). However, even if it is possible to include data from various sources, such as observations, movie sequences and conversations, written text is the most common (Krippendorff, 2004). The results of the analysis process are often presented as concepts, themes or categories that aim to elucidate and describe the phenomenon (Graneheim & Lundman, 2004; Hsieh & Shannon, 2005; Krippendorff, 2004).

Phenomenology and hermeneutics

In Study II, the approach is phenomenological hermeneutical according to Ricoeur (1913-2005) (1976, 1998, 2008) in that the aim is to both understand what the different texts talk about and, moreover, as a continuation, explain the lived experience of the critically ill patients.

Phenomenology is focused on the subject and its essential meaning as it arises and is experienced in our life-world. Furthermore, phenomenology aims to direct study and describe a phenomenon as a lived experience. The structures of various types of experiences, such as perceptions, thoughts, memories, beliefs, feelings, desires, and bodily awareness are of interest (Thomasson & Smith, 2005). Our consciousness is always a consciousness of "something" and the world is always a world of "someone" (Crotty, 2003). The life-world is an important concept in phenomenology and Ricoeur (2008) expresses that the life-world is the subsistence where we exist together with others and in which we have a communicative relationship to (Kristensson Uggla, 1994). Ricoeur was influenced by many philosophers such as Kant, Husserl and Heidegger, when he advanced phenomenology and developed a viewpoint where phenomenology not only inspects but communicates (Kristensson Uggla, 1994; Lindseth & Norberg, 2004).

As in phenomenology, the lived experience of the world is central in *hermeneutics*. However, hermeneutics is about interpretation and understanding, and its focus is on meaning and understanding in context. Furthermore, the essence of beliefs and values is illuminated through hermeneutics (Charalambous, Papadopoulos, & Beadsmoore, 2008). To reach a reasonable interpretation, both pre-understanding as well as a detailed description of the context are of importance, since the experience of a phenomenon is dependent on the circumstances (Lindahl, Sandman, & Rasmussen, 2005). However, Ricoeur (1981) developed a new direction in hermeneutics. He wanted to build a bridge between explanation and understanding and claimed that the process of interpreting texts is not about understanding the author and the event, rather it is to understand what is being talked about (Kristensson Uggla, 1994), "*the thing of the text*" (Ricoeur, 2008 p 127).

Polkinghorne (1995) and McCance, McKenna, & Boore (2001) mean that narratives can be used to describe human experiences and actions in a fruitful way. Ricoeur (1998) has discussed the concept of narrative and means that through narrative new meanings can evolve from a person's experienced world. Narrative can be seen as a link between the told story and action. The narrative is related to the lived world of the narrator and contains a direction that makes its wholeness into something greater than its parts. A narrative reveals a new world, not behind the text but in front of the text (Lindseth & Norberg, 2004; Ricoeur, 2008). According to the philosophy of Ricoeur (1998) there cannot be only one method of working with the structural analysis of narratives and, in recent years, the concept of narrative has been used in a variety of disciplines (Edvardsson, Rasmussen, & Riessman, 2003; Elwyn & Gwyn, 1999; Frid, Bergbom, & Haljamae, 2001; Josephsson, Asaba, Jonsson, & Alsaker, 2006; Lindahl, Sandman, & Rasmussen, 2006). Using narrative research within the nursing and medical professions is essentially new but it has been presented as an opportunity to tap into patients' experiences.

Feasibility studies

The purpose of Study IV was to explore if it is possible to implement a full-scale sound intervention in an ICU setting, i.e. it was a so-called feasibility study. Feasibility studies aim to investigate and evaluate research procedures prior to conducting full-scale clinical trials, but they do not attempt to evaluate and measure effects. Thus, their purpose is to assess the critical parameters needed to design the main study and they provide opportunities to enhance and develop the research procedures (Arain, Campbell, Cooper, & Lancaster, 2010; Polit & Beck, 2012). Examples of interesting and valuable areas are:

- Standard deviations of the outcome measure, can be used to calculate the sample size
- The randomization process
- The recruitment process
- Eligible patients
- Testing the instruments to be used
- Calculating resources required.

Feasibility-studies cannot be randomized, the analysis should be presented in a descriptive way, not by testing hypothesis; this comes later in the full-scale study (Arain et al., 2010; Lancaster, Dodd, & Williamson, 2004). What is important is not a primary outcome, but rather a sample size that is sufficient to assess the critical parameters.

Some equate feasibility studies and pilot studies (Polit & Beck, 2012), while others define a pilot study as a miniature study aimed to test whether the components work together (Arain et al., 2010).

Setting

Studies I and II

In studies I and II, all included patients were recruited from the same general medical-surgical ICU. The hospital chosen, Södra Älvsborg Hospital (SÄS) Borås, is a normal sized Swedish county/regional hospital where all specialties are represented. Approximately 440 000 patients are treated there each year, and the number of employees is about 4.200. The ICU has 8 beds and approximately 800 care events each year.

Study III

Study III consisted of two parts where all included participants were recruited from nine ICUs within the Region Västra Götaland and Region Halland. The ICUs chosen were a convenience sample as they were located in a geographically manageable area. The hospitals represented were; Halland Hospital (two ICUs), Skaraborg Hospital (SKAS) (one ICU), Kungälv Hospital (one ICU), Sahlgrenska University Hospital (SU) (four ICUs) and Norra Älvsborg County Hospital (NÄL) (one ICU). All of the ICUs had the same staff to patient ratio (1:1), but varied in number of patients per year, age (built or rebuilt 1978-2012) and number of beds (8-16 beds). Seven general and two specialized ICUs were represented (one neuro-surgical ICU and one thoraco-surgical ICU). The ICUs included in Studies I and II were excluded since staff working there were considered to have more knowledge in sound and noise.

Study IV

In Study IV, which was designed as a feasibility study in advance of preparing a full-scale study, a general medical-surgical ICU in a county/regional hospital in western Sweden (the same ICU as in study I and II) was chosen for data collection. The idea for an intervention took form in 2009, and in 2009-2010 a project team led by Professor Ingegerd Bergbom and senior lecturer Berit Lindahl planned and refurnished a two-bed ICU patient room at ICU SÄS (the experimental room). An identical two-bed room was left unchanged for comparative studies (the control room). The aim was, in accordance with previous research (Dijkstra, Pieterse, & Pruyn, 2006; Fontaine, Briggs, & Pope-Smith, 2001; Rashid, 2006; R S. Ulrich, 2006) and business innovations, to create a room where sound, light and aesthetics were improved.

Sound improvement

In the experimental room, a new suspended wall-to-wall ceiling replaced the existing ceiling (constructed from a suspended 13 mm gypsum board provided with 20 mm

fibrous absorbent). Additionally, a low-frequency absorber was provided. Baseline measurements in the two rooms during the renovation period and exactly at completion of the rebuilt room showed a slightly lower reverberation time (RT) for low frequencies and better speech clarity in the renovated room.

Light improvement

The experimental room was equipped with a new circadian lighting system aimed at following natural day and night light rhythms, levels and colors of light. The system is described in more detail in a recently published paper (Engwall, Fridh, Bergbom, & Lindahl, 2014). Aiming at preventing hallucinations, the idea was to create a ceiling as smooth and visually plain as possible and, therefore, all ceiling armatures and ceiling-mounted hangers were removed in the experimental room. The new lighting system was placed on four ceiling pendants, one on each side of the patient.

Aesthetics

In the experimental room, the wall behind the patient was fitted with a wooden wall-mounted headboard to help the patient feel a sense of security. Moreover, the wall in front of the patient was made as plain as possible. All walls were painted a muted green pastel color. Finally, a new floor and new textiles in the form of drapes and curtains were provided.

Table 5. An overview of the design of the studies in the thesis.

Study	I	II	III	IV
Focus	Sound pressure levels Early signs of ICU delirium Critically ill patient's memories of sound and noise in the ICU patient room	What it means to be critically ill and surrounded by sound and noise	Staff knowledge concerning sounds and noise in ICU Staff suggestions concerning improvements	Feasibility of a clinical complex sound intervention study in ICU Sound measurements Incidence of ICU delirium
Design	Explorative Descriptive Comparative	Explorative Descriptive	Descriptive Explorative Comparative	Descriptive
Data collection	Sound measurements Early signs of ICU delirium protocol Qualitative research interviews	Qualitative research interviews	Web-based questionnaire Qualitative research interviews	Observations Sound measurements CAM-ICU tool
Sample*	13 critically ill patients treated in the ICU	13 critically ill patients treated in the ICU	305 physicians, ICU nurses and enrolled nurses working bedside in the ICU 20 physicians, ICU nurses and enrolled nurses working bedside in the ICU	31 critically ill patients treated in the ICU
Data analysis	Descriptive statistics Content analysis	Phenomenological hermeneutical method	Descriptive statistics Content analysis	Descriptive statistics

*Eligible participants for each study

Design

The critically ill patient being cared for in the sound intensive ICU patient room has been the focus in this thesis. The purpose of the studies has been to generate as a broad picture of the knowledge area as possible; that is, to not only find the general but also to seek the unique. Therefore, a multiple-method design has been employed, including both quantitative and qualitative analysis. Data were collected through qualitative research interviews, sound measurements, instruments and questionnaires. Descriptive and comparative statistical analyses were used in the studies whose aims were to find general patterns or relationships. Furthermore, in the studies where the aim was to seek understanding and meanings, qualitative content analysis or phenomenological hermeneutical methods have been used. The analysis in Study II has been guided by Ricoeur's phenomenological hermeneutical interpretation theory (Lindseth & Norberg, 2004; Ricoeur, 1976).

Data were collected both prospectively and retrospectively to meet the various objectives represented in the four studies. The sound measurements in Studies I and IV were made prospectively while the data collection procedures (interviews) in Studies I and II had a retrospective approach.

Participants and population

Studies I and II

The participants in Studies I and II consisted of the same study group. The patients were recruited using convenience sampling and the exclusion criteria were: head injury, known hearing impairment and dementia. Nineteen patients were recruited initially. Of them, three died in the ICU, one declined to participate further and two could not be contacted for an interview. The final study group consisted of 13 patients. Data were collected between May 2007 and July 2008. Studies I and II are to be seen as pre-studies in that they describe the sound environment and patient experiences and form the basis for the care environment intervention presented in Study IV.

Study III

Study III consisted of two separate studies where the underlying intention was to gather rich and informative data in order to explore and describe two aspects of a phenomenon. There was a questionnaire study where the final study group consisted of 44 physicians, 199 ICU nurses and 62 enrolled nurses (n=305) with a mean age of 45.5 years, and an interview study consisting of three physicians, ten nurses and seven enrolled nurses between 32 and 62 years (n=20). Data were collected from December 2012 to October 2013.

Study IV

All patients cared for either in the experimental room or the control room were asked to participate in study IV. Depending on the nature and design of the intervention, patients were randomized before recruitment and, for organizational reasons, staff in charge were responsible for the randomization process which consisted of randomly

drawing a numbered ticket from a jar to determine patient placement. A quasi-randomized clinical trial design was used, meaning that when both rooms were empty, the patient being admitted was randomly placed in one of the rooms. If one bed was occupied, the next incoming patient was placed in the empty room. If there was one patient in each room, the next incoming patient was randomized in the same way. One hundred fortyone patients were admitted to one of the two two-bed rooms between October 1st, 2012 and April 24th, 2013. The inclusion criteria were: LoS 48 hours or more, aged 18 or older, not admitted due to intoxication and had the ability to communicate in speech or writing. In this study, 86 had a LoS of 48 hours or more, and 14 patients were excluded. Of the 72 patients eligible, 13 were missed, five declined to participate, one had protected identity, 16 had a severe illness and for six patients, sound measurements were missing or damaged. The final study group consisted of 31 patients. Six were cared for in the experimental room and 25 in the control room.

Data collection

Several methods were used for collecting data. Sound measurements were conducted in Studies I and IV, and interviews were performed in Studies I, II and III. In Study III, the staffs' actual knowledge about the sound environment was evaluated using a web-questionnaire. In Studies I and IV, ICU delirium was identified using two different protocols.

Sound measurements

In Studies I and IV, sound measurements were taken, but in varying ways and using different types of equipment. In Study I, recording devices were placed close to the each patient's head for 24 hours (Figure 3). dB(A) sound pressure levels with a one minute averaging interval were measured for all patients using a Bruel & Kjaer 2260 sound level meter. Equivalent levels sampled for 24 hours (LAeq24h) and A-weighted maximum levels (LAFmax) were given.

In Study IV, microphones for sound recording were placed above each bed. Sound data was continuously collected day and night, and data were processed using a software program called Sound Monitor, and then stored on a computer in the room. The software calculates the sound pressure level according to standard formulas, with different weighting of the sound (A-weighted, C-weighted, and without frequency weighting). Sound pressure levels were collected at intervals of 30 seconds and were logged with the following different measurements: LAeq, LAFMin, LAFMax, LCeq, LCPeak, LZeq, and LZPeak. Subscript F denotes FAST time weighting, an exponential time constant of 125 ms. This data can be used later to analyze the sound characteristics of the room.

In the experimental room, the goal was to hide the equipment as much as possible. The computer and cables were placed above the suspended ceiling, while the microphones were installed in holes in the ceiling plates such that only 10 cm long cylinders with 13 mm diameter beds were visible. In the control room, the cables were visibly taped to the ceiling, and the computer was placed on the top of a cabinet.

Figure 3. An ICU patient room. The arrow shows the placement of the sound recording devices (Study I).

Qualitative research interviews

The aim of the qualitative research interviews in the context of intensive care was, firstly, to emphasize the patient's own narrative concerning being critically ill and cared for in a sound intensive patient room (Studies I and II) and, secondly, to identify caregivers' views of the issue (Study III). A narrative approach was used in all three studies since it had been suggested that narratives or told stories are the primary ways of receiving the meaning of a specific phenomenon (Kohler Reissman C, 1993; Lindseth & Norberg, 2004).

In Studies I and II, thirteen patients were interviewed 2 to 35 days after being discharged from the ICU. By using interviews, the intention was to capture the patients' own stories, their own narratives about their recollections and what it is like to be a patient in the ICU. All respondents received verbal and written information about the aim of the study. They were also asked to give their written consent. The interviews were conducted on the hospital's general wards or at home depending on the patients' preferences. They were conducted by Berit Lindahl and transcribed verbatim by the author. At the beginning of the interviews, the patients were informed in detail about the aim of the meeting and were asked open-ended questions or prompted by remarks such as "Can you please tell me about your experiences and memories from your time in ICU?" or "*I am interested in hearing about your experiences from your time in ICU and especially your recollections of sound and noise*.". The patients were encouraged to speak freely and openly about the subject, and follow-up questions were asked to ensure that the sound perspective was covered and that there were no misunderstandings.

In Study III, in the interview study, data collection consisted of interviews with ICU staff (physicians, ICU nurses and enrolled nurses) concerning suggestions for improvements. Ward managers at the ICUs were asked to choose two or three physicians, ICU nurses or enrolled nurses for an interview concerning sounds and noise in the ICU. Once the names of those chosen were received from the ward manager, each person was sent an e-mail containing an information sheet regarding the study. Thereafter, a time and a place for the interview were agreed. In the end, all interviews took place at the interviewee's place of work. The interviews were performed using a narrative approach and started with a question or remark like "*Please tell me about your thoughts on the sound environment inside the ICU patient room*." or "*Please tell me about the sound environment in the ICU patient room.*". The interviewees were encouraged to speak freely about sound and noise in the ICU, and, as necessary, supplementary questions concerning suggestions for improvement were asked. The interviews varied in lengths from about 25 to 50 minutes. All interviews were conducted and transcribed verbatim by the author.

Questionnaires

Part one in Study III was designed as a descriptive retrospective study in which the data collection consisted of a knowledge questionnaire that was distributed to the three main professional groups working bed-side in ICUs in Sweden (physicians, ICU nurses and enrolled nurses). The questionnaire was designed by the British researcher, M Christensen, and has previously been used in a British context where the population consisted exclusively of ICU nurses (n=96) (Christensen, 2005). Christensen was contacted per e-mail regarding permission to use the instrument, after which he sent the whole questionnaire. The first five questions were excluded as they regarded nationality. The final questionnaire consisted of 14 questions; the first four questions concerned sex, age, profession and years at an ICU, and the last ten were sound-related questions. The instrument was translated by a team consisting of tree members; the author and a co-worker, both familiar with intensive care issues and native Swedish speakers, and a native English speaking researcher. In accordance with White & Elander (1992), a back-translation method was used and in accordance with Maneesriwongul & Dixon (2004), the original, translated and back-translated versions were compared thoroughly. The questionnaire and one reminder were distributed per e-mail. Additionally, the ward managers at each department were asked to encourage the staff to answer the questionnaire. The answers were stored using analysis software, Webropol 2.0.

Instruments and observation protocols

In two of the studies (I and IV) the aim was to explore sound and its impact on ICU delirium. For this purpose, two different protocols were used. In Study I, an observation protocol was used to identify early signs of ICU delirium. The protocol was devised by Granberg-Axell et al. (2001) and is based on an observational study performed in an ICU where intubated and ventilated patients were observed during the weaning procedure, on the extubation day and the two following days. The protocol consisted of the twenty subcategories identified in the observational study, divided into four categories: behavior, gaze, communication and sleep. Observations were made by the nurse in charge once an hour during a 24-hour study period.

In Study IV, an ICU delirium was assessed once a day using the Confusion Assessment Method for the ICU (CAM ICU) tool. This tool is designed to identify acute confusion related specifically to intensive care. The instrument includes four criteria: 1) Acute Change or Fluctuating Course of Mental Status, 2) Inattention, 3) Altered level of consciousness and 4) Disorganized thinking. CAM-ICU was developed and validated for the ICU context by Wesley Ely and his research team at the Delirium and Cognitive Impairment Study Group, USA, (Delirium and Cognitive Impairment Study Group, 2010, Ely et al., 2001). Chatarina Larson and co-workers translated and validated the instrument for a Swedish context (Larsson, Axell, & Ersson, 2007). Larsson was contacted for permission to use the translated instrument. Since data for multiple studies were collected in the two intervention rooms (not included in this thesis), data were collected by the author and a colleague who were on site at the ICU five days a week. During evenings, nights and weekends, two research nurses or staff in charge were asked to assist the researchers.

Patient records and observations

In Studies I, II and IV, clinical and demographic data, including ICU LoS, age, Simplified Acute Physiology Score (SAPS III), pharmacological treatment, ventilator treatment and nutrition, were collected from medical records and observation sheets. Study IV was designed as a feasibility study for a quasi-randomized clinical trial; therefore, it was designed as a prospective comparative-explorative study. Data collection consisted of observations and documentation of methodological problems and possible solutions continuously identified during the study period.

Analysis

Statistical analysis

The Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA version 18-22) was used in all quantitative analysis. Level of significance was set to 0.05.

Study I

In Study I sound levels were analyzed using parametric statistics including mean values. Level of significance was set to 0.05. The Spearman's rank correlation test was used to analyze relationships between early signs of delirium and sound levels (LAeq and LAFmax),

Study III

In Study III, non parametric tests were used to analyse differences between groups of professions and groups of ages: Chi-square test, and when required, Fisher's exact test was used for categorical data and the Mann-Whitney test was used for continuous data when comparing groups. Demographic data were analysed using descriptive statistics.

Study IV

In Study IV, sound levels were analysed using descriptive statistics and presented in charts. Demographic data were analysed using parametric tests including both mean and median levels. Clinical data were analysed using descriptive statistics and presented in number of patients and percent.

Content analysis

In Studies I and III, conventional manifest content analysis according to Hsieh & Shannon (2005), was used. The analysis started with several careful readings by the full text. Subsequently, key concepts were identified, organized and coded and, thereafter, codes were sorted into categories and subcategories related to the text material. Finally, definitions for each category were developed. Moreover, in Study I, to sumarize the number of early signs of ICU delirium, quantitative content analysis was used.

Phenomenological hermeneutical method

In Study II, the aim was to illuminate the meanings of being a patient in an ICU environment surrounded by sounds and noises. Therefore, a phenomenological hermeneutical analysis method was chosen. The phenomenological hermeneutical method for nursing research, a Nordic qualitative method developed by Lindseth & Norberg (2004), is inspired by Ricoeur's writings and, thereby, based on two well-known philosophical approaches; phenomenology and hermeneutics. A central issue in the method is how to obtain knowledge and disclose truth about the essential meaning of being in the life-world. When a discourse is transformed into text, the text attains an autonomous position and the meaning it mediates opens up for an understanding of a possible being/existence in the world. In the analysis process, a single fundamental truth is not expected to find, as the whole truth can never be completely understood. Instead, possible meanings are sought (Lindseth & Norberg, 2004). The phenomenological hermeneutical analysis process follows three steps: naïve reading, structural analysis and comprehensive understanding.

Naïve reading

With the primary goal of open up the whole text and allow it to speak to the reader, the interview text was read several times. The natural attitude was left aside and a phenomenological way of thinking was adopted. Since this first analysis was a first conjecture or guess, it had to be validated in the next step, the structural analysis.

Structural analysis

According to Lindseth & Norberg (2004) the aim of the next step is to explain and interpret the text and, therefore, a thematic structural analysis was performed. When the whole text was read again, sentences that illuminated the essential meanings of lived experience were of interest; in this case the meaning of being critically ill in a sound-intensive ICU patient room. Similar sentences were condensed and grouped together in themes. According to Ricoeur (1976), the text is autonomous i.e. the text expresses its own meaning. Therefore, in this phase, it is important to view the text as objectively as possible. Ricoeur (2008) claims that this step makes it possible to both explain and understand a text, not what the author intend to say, but what the text is about. The identified subthemes and themes can then be presented in different ways. The most common way is to present each theme separately and give a brief summary of the findings (Fagerberg & Norberg, 2009; Hallden, Christensson, & Olsson, 2005). In order to further highlight and abstract the phenomenon and to move beyond the text itself, two composite stories were constructed with the help of the emerged

themes and subthemes (Polkinghorne, 1995). Furthermore, the findings were verified by quotations. Since the first structural analysis did not cover all, one more structural analysis of the data was needed, resulting in a one new theme and three subthemes. The findings from this structural analysis were not included in the composite stories.

Comprehensive understanding
In this last step, the aim was to put together the pieces as a whole again. Thus, the pre-understanding, the naïve understanding, the structural analyses and relevant literature were included when the reflections were summarized. This phase aims to broaden and deepen the awareness, but also critically reflect the findings.

Ethical considerations

All studies in this thesis were designed to follow the ethical guidelines and principles developed by the world Medical Association Declaration of Helsinki. This standard requires a review by an independent authority with regards to ethical considerations and, consistently, respect for the autonomy of the participant. Ethical considerations are especially required when asking seriously ill patients to participate in a research study as they are in a vulnerable state. It is to be considered that their fatigue, illness and influence of sedative drugs make it difficult to understand and mastering information. For Studies I, II and IV, ethical approval was obtained from the regional ethics committee at University of Gothenburg (Dnr 069-07 and Dnr 695-10).

According to the Belmont report (Sims, 2010; The Belmont report, 1978), the research must not harm anyone, but has the intention of doing good. Sound measurements included acoustic parameters only and, thus, they did not impact the patient physically, nor did they compromising patient privacy (Studies I and IV). In Study IV, the patients in the rebuilt control room were not expected to come to harm since the differences between the two interventions rooms were considered small. Moreover, the care, the monitoring and the staff to patient ratio was the same in the two rooms. Estimates of delirium with the CAM-ICU instrument only took 5 minutes to complete and, thus, it was not considered being burdensome for the patient. The interview after the ICU stay was the most time consuming and most onerous part for the patient and, therefore, these interviews were carefully planned in collaboration with the patient.

Whether people asked are to determine if they really want to participate in a research study or not, properly information is required. In Studies I and II, patients who underwent elective surgery with expected need of intensive care afterwards, were asked for participation at the pre-operative assessment visit; they received both verbal and written information about the study before they signed a consent form. In cases of acute admission to the ICU (Studies I, II and IV), the patients themselves were asked only if they were considered to be fully awake and oriented. If a patient was unable to read and understand the verbal and/or written information, the patients' next of kin's were informed about the study and asked for a temporary permission. In such cases, the patient was informed both verbally and in writing after discharged from ICU, when he/she had recovered. Then, if he/she declined participation, data was destroyed. The verbal and written information included a brief description of the purpose of the study, what participation would entail, that participation was voluntarily and that the patient

could, at any time, withdraw from the project. The information also included data concerning who was responsible for the study and expected benefits. Finally, they were guaranteed anonymity when the results were presented.

For Study III, no formal application to the ethical board was required according to the Swedish law. The participants were first contacted by an e-mail, where they received information about the study; the purpose, the interview and that their participation was voluntary and that they could at any time withdraw. At the time for the interview, they were informed again, both verbally and by a written information sheet. For all included studies, the chief clinicians were contacted for consent before the data collection started.

RESULTS

The main findings of Studies I-IV are summarized below:

- Sound levels in the ICU patient rooms are higher than the official recommended levels.
- LAF max levels exceeded 55 dB 70-90% of the time, meaning that quiet periods for rest and sleep were few and short.
- No correlation between high sound levels and number of early signs of ICU delirium could be identified, however; one patient describes how sounds continuously become a part of dreams and unreal experiences, indicating that more research in the area is needed.
- Patients hear, register and remember sounds from the ICU patient room.
- Patients experience the sound environment in the ICU patient room as complex and varied.
- The sounds in the ICU patient room can be perceived as safe and secure, but also as annoying, frightening and unpleasant depending on the nature and source of the sound and the condition of the patient.
- Since the seriously ill patient is unable to control the ambient sounds, the unpredictable shifts between silence and disturbing sounds impact the patient brutal and ruthless.
- The staff who work bed-side in the ICU, have inadequate knowledge concerning sound, noise and its impact on man.
- Staff suggestions for sound improvements included actions at several levels: improvements concerning staff's own care actions and behavior, improvements requiring staff interactions and improvements concerning physical space and technical design.
- A complex clinical intervention study, with continuous sound measurement is time and resource consuming, but it is feasible.
- A complex clinical intervention study with continuous sound measurement requires close collaboration with stakeholders both before and during the performance, as well as a well thought-out resource calculation.

Sound pressure levels in the ICU patient room

In two of the studies (Studies I and IV) sound pressure levels (SPL) were recorded and measured inside the ICU patient's room, but since Study IV was designed as a feasibility study, no comparative values were reported. Sound measurements in Study

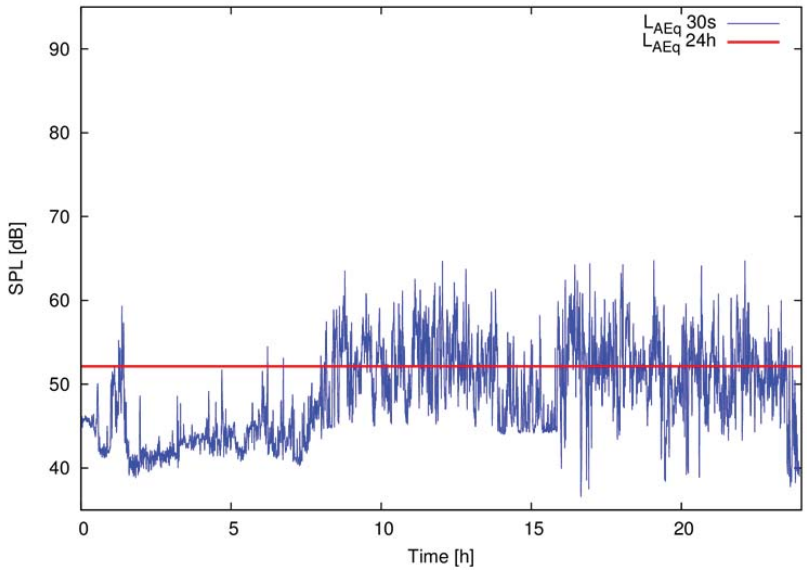

Figure 4. Example of measured sound pressure levels (SPL) for one randomly chosen day (00-24) in Study IV. The A-weighted equivalent level (LAeq) is measured in 30 s intervals over 24 hours (in blue). The red line shows the LAeq for the entire 24 hour period.

I resulted in twelve 24-hour period measurements. LAeq for 24 h for these were 53 dB (SD = 1.11). LAFmax levels ranged from 81 to 101 dB and LAmin levels ranged from 31 to 47 dB. LAF max levels exceeded 55 dB 68- 89% of the time.

In Study IV, in chart form, four randomly selected 24-hour periods from the two study rooms were presented. The graphs presented in Study IV, show a large variation in LAeq levels and LAF maximum levels. Moreover, the range between the quietest and loudest 30 second periods (LAeq within 30 min) shows strong variations, variations greater than the variation between the two rooms. Figure 4 shows an example of sound measurements from one randomly chosen day.

Patients' experiences of sounds in the ICU patient room

The two studies describing patients' experiences of the sound environment in the ICU patient room had different approaches; Study I described the memories of the patients while Study II focused on the meanings of being cared for in a sound-intensive ICU patient room. Both studies revealed that participants experienced and interpreted the ambient sounds subjectively and in different ways, that is, sounds could be perceived both positively and negatively. Moreover, patients also experienced sounds differently at different times. Factors that influenced the perception of the surrounding sounds were participants' earlier experiences and backgrounds. Although the approaches were different, the conclusion is that the patients are in a vulnerable position where feelings of powerlessness are central. Table 6 gives a comprehensive overview and summarizes the categories and themes of the two studies.

Table 6. A presentation of the content analysis in study I and the structural analyses in Study II

Study I Categories and subcategories	Study II Themes and subthemes
Sounds related to the setting	**I feel safe and secure when being in a caring and familiar atmosphere**
Calm and peaceful	Feeling safe and secure when relating to earlier experiences
Too quiet	Feeling secure when hearing the staff work and talk
Hearing sounds from outside	Feeling secure when hearing the equipment working well
	Feeling safe when hearing visitors to the Neighboring patient
Sounds related to the staff	**I am mobilizing my strength and inner security**
No memories of sounds related to the staff	Coping with noise and sound with calmness
Aware but not disturbed by the staff's presence	Trying to keep calm
No possibility of escaping	
Conversations about the own treatment and care	
Sounds related to the other patients in the same room	**I feel uncomfortable by being trapped in an uncontrollable situation**
Aware but not disturbed	Feeling guilty when unable to be active
Involuntary listeners	Being trapped, surrounded by uncomfortable noise
No possibility of shutting off the unwanted sound	
Scaring and frightening sounds	
Sounds related to the technical equipment	**I am an invisible auditor in an imposed drama**
Lacked memories of sounds related to technical equipment	Feeling helpless hearing frightening noises from roommate
Frightening thoughts about the meaning of the sound	Being disappointed being left without help
Safe and friendly	Hearing fragmentary conversations
Sounds as a part of dreams	**I am left alone in a strange and demanding world**
Sounds integrated into dreams	Feeling awkward and uncomfortable when hearing the staff talk
	Feeling afraid and abandoned in the quiet of the night
	I am struggling with unreal experiences interwoven with sounds
	Facing diffuse sonic experiences
	Facing a confusing "movie"
	Facing demands related to sounds in dreams

Being surrounded by unfamiliar sounds (Study I)

Despite patients' severe illness and influence of fatigue and drugs, they remembered and could describe their experiences of a variety of sounds and noises. It was mainly sounds from the environment, the staff, other patients in the room and technical equipment that were highlighted and described more in detail. Being cared for in the sound-intensive patient room at ICU was described as being in an unfamiliar and complex sound environment, surrounded by sounds they could not turn off or escape from. It was also stated that sounds could have both positive and negative impact on patients; sounds could provide security and structure in the new environment, such as creating context and assist in the orientation of time and place. However, disturbing ambient noise could also contribute to adverse effects, such as annoyance, fear and anxiety and/or disruption to sleep and rest.

Being unprotected and naked showered by unexpected and unpredictable sounds (Study II)

Being cared for in the sound intensive ICU patient room was interpreted as being in an uncontrollable state with no ability to influence the situation. Since the patient was critically ill, tired and connected to various cables and hoses, it was impossible to protect or otherwise escape the sounds. Constantly, the sound environment alternated. From being acceptable and giving the patient a feeling of "being at the proper pitch", to shorter or longer periods of almost unbearable noise, where the patients experienced a sense of "being surrounded by piercing sounds". Sounds could not be predicted; they had different characteristics and came suddenly and unexpectedly from various directions. The patient had, in worst case, a constant feeling on edge, thus, spatiality could include both meaningfulness and meaninglessness. Since no one, neither the nursing staff nor relatives, seemed to understand, they felt abandoned and alone in the situation. If the patient had a prior history of hospitalization, or, had internal capacity to manage the sounds, the sounds became bearable.

ICU delirium - incidence, correlation to sounds and patient experiences

Since there is a lack of studies focusing on sound and noise and its physical effects on critically ill patients, one of the intentions of this thesis was to examine the relationship between delirium and sound. Study I, which was designed as a pre-study prior to the intervention study, studied delirium using a protocol, the early signs of delirium protocol. During the same time, SPL was registered in the room. In four patients (n=12), seven or more early signs of delirium were identified. None of these exhibited signs of hyperactive delirium, such as plucking behavior, motor restlessness or aggression. However, in the comparative analyzes concerning connection between high number of signs of delirium and high noise levels (Laeq and Lamax levels), no significant correlations were identified.

In Study IV, the instrument CAM ICU was used to estimate delirium in the included participants. In seven patients (22,6%) (n=31), ICU delirium was identified at some time during the ICU stay. No correlation analyzes were performed. Study IV also lifts up the challenges of daily estimation of ICU delirium with the CAM ICU instrument. In Studies I and II, one patient described a condition of ICU delirium including dreams and unreal experiences. The unreal experiences were perceived as film sequences and included both sounds and images. Since the dreams were illogical in their expressions, the patient found it difficult to identify the sounds and the sound sources and, therefore, even if the sounds were not scary in themselves, the patient experienced the sound as stressful and unfriendly. Some sounds were perceived as very unpleasant and, therefore, the patient tried without great results to take measures and turned from side to side in the bed or stopped fingers in her ears. Some sounds in the dreams were connected to orders or requirements.

Staff knowledge concerning sounds and noise

Staff, who work bed-side in the ICU, has an important position in terms of reducing sounds and noise in the patient room. Therefore, their knowledge in the area is cru-

cial. In the web-based knowledge questionnaire, sent to 1047 physicians, ICU nurses and enrolled nurses, it was found that all respondents (n= 305) had and inadequate knowledge concerning sounds and noise (Study III). None of the respondents answered all ten questions correctly; the best result was eight correct answers. The question most respondents answered correctly was the question concerning which part of the autonomic nervous system that is stimulated by excessive intermittent noise levels; 81% (n=305) answered this question correctly. The most challenging question was the one concerning chronic physiological changes that may occur in people exposed to excessive intermittent noise; only 3% answered this question correctly. In a comparison between the professions, physicians showed a better result than the other in six of the questions, in four of these, the difference was significant. Enrolled nurses had the best results in the question regarding WHO recommendations for sound and noise in hospitals. No difference in knowledge level was found between elderly (46-65 years) and younger (18-45 years) staff in a comparison analysis.

Suggestions for improvements

Despite staffs' poor level of knowledge (Study III), the interviews performed in the same study showed that many were aware of the sounds in the ICU patient room and could provide suggestions for improvements (Study III). The suggestions identified were divided into three levels: "improving staff's own care actions and behavior", "improving strategies requiring staff interactions" and "improving physical space and technical design".

In the first category, suggestions were focused on concrete measures addressed to the staff, actions considered to be relatively simple to implement. Adjust the alarm settings and lower the sound levels of the alarms were the suggestions most mentioned. Reduce noise from conversation and coordinate care activities were other examples. All these suggestions require awareness and a proactive approach of the individual professional carer. The next level of suggestions required collaboration between actors, which considerably complicated the procedures. Reminding each other, offer a timed period of rest, and involve the management were some of the measures deemed necessary to bring about change. Here, differences in knowledge level of and lack of understanding of the phenomenon hampered improvements. The final level consisted of suggestions that required relatively large and expensive efforts. One-bed rooms, sound absorbing arrangements and textiles in various forms were some examples. Some interviewees expressed hopelessness when it came to these proposals because they had previously drawn attention to the noise problems in the unit, but received no response from the management.

Feasibility of a complex intervention in ICU

Implementing a well-functioning complex intervention study in ICU requires great efforts, both during the planning phase and during the performance. Therefore, it was found necessary to perform a feasibility study before starting the full-scale study. The results presented in Study IV, showed that problems related to the trial itself were issues found almost exclusively, and not issues related to or influenced by external factors.

Several parts need to be improved before conducting the full-scale study;

1. The randomization process must be improved.
2. Recruitment of patients' must be performed both day and night and therefore, resources for this are required.
3. The procedure for sound measurements need to be developed, a network connection is necessary as well as available and well-educated researchers.
4. A more extensive training of the CAM-ICU instrument is required.

DISCUSSION

Reflections on the findings

Sound pressure levels in the ICU patient room

In this thesis, it has been shown that critically ill patients are cared for, sometimes for weeks or months, surrounded by noise levels comparable to a busy road. In Study I, where sound measurements were performed in ICU patient rooms for a total of 13 days, it was found that LAeq levels in 24-hour periods to be between 51 and 55 dB. This is indeed comparable to many other previous studies, but the levels were higher than recommended existing guidelines. Moreover, the levels registered were much higher than those we experience in our homes, where we live and sleep in good health. In addition, it was found that the noise environment consisted of a variety of intermittent sounds, i.e. sounds of different strengths and frequencies that came and went, which is in accordance with other studies (MacKenzie & Galbrun, 2007; Tegnestedt et al., 2013; Xie, Kang, & Mills, 2013). Patients also had very short periods of peace and quiet, that LAF max values exceeded 55dB approximately 80% of the time, a result consistent with both Swedish and international studies (Ryherd et al., 2008; Simons et al., 2014). Figure 4 clarifies this; it shows an example of how sound levels varies during a day. Although the sound levels were slightly lower at night, the sudden spikes were constantly repeated. In Sweden, there are no limits or specific guidelines regarding noise levels in ICU patient rooms, something which is remarkable.

The experience of being surrounded by sounds and noise

As described earlier, sound is experienced subjectively, which means that the acoustic data provide only part of the truth. Therefore, patients' own stories were of great interest for this thesis. It was found that more patients than expected hear what is going on in their room; they are aware of and remember many sounds from their stay in the ICU despite their severe illness and fatigue. To the author's knowledge, there are no previous studies that specifically investigate patient experiences and perceptions of sound and noise in the ICU patient room. The meaning of being critically ill and surrounded by sounds and noise was of particular interest because this very subjective experience is central in caring sciences and, in this thesis, it is argued that the meaning individuals attribute to the sound influences their ability to handle sound. Josephsson (2004) agrees and states that the environment, both the concrete physical surroundings and the relationships to other people, affects our understanding of our selves and how to act. Studies I and II show that patients are affected by sounds which generate various kinds of feelings.

The patients' stories also confirm the results of the acoustic measurements as they describe the sound environment as both varied and unpredictable. At best, the ambient sounds became a resource which supported the patient. Hearing was shown to be an important property regarding orientation in time and space, and hearing staff work quietly and systematically in the patient room was perceived by many as both calming and reassuring. However, depending on the patient's condition, both sound and silence could be perceived as intimidating. An interesting patient story in Study I raised the importance of hearing in relation to orientation in time and space. The

patient woke up in the middle of the night in a room where the staff, in the interests of the patient, had turned off the lights and were trying to be quiet. In the silence and darkness, he was unable determine where he was, and he experienced the silence as very unpleasant as it signaled both loneliness and abandonment. The same narrative also raised the problem of the vulnerability of seriously ill patients in that he was connected to a ventilator and unable to express his needs (E. Gjengedal et al., 2013).

The findings in this thesis indicate that the surrounding sound causes suffering for patients; this is what Lindholm & Eriksson (1993) call "suffering caused by care", i.e. suffering that is in no way connected to the patient's disease or injury. On the contrary, it is suffering caused by the care organization or by the professional caregivers, consciously or unconsciously. In many cases, this suffering is hidden because the patient cannot express their needs (Arman & Rehnsfeldt, 2006). Above all, care should not cause harm; it should be curative and caring. The noise environment in the ICU is complex and when it is combined with a feeling of unfamiliarity, it is not an asset to all. Nightingale (1859) expressed early on that "*Unnecessary noise, then, is the most cruel absence of care which can be inflicted either on sick or well*". Thus, she considered that it was a nurse's duty to ensure that patients are cared for in a quiet and calm environment. Oddly enough, no nursing theorists since have illuminated the phenomenon of sound and its importance to sick or vulnerable humans. From a philosophical perspective, Eriksson (1991) stresses that a caring act is one which take over when a patient is unable to meet his or her own needs; it is a responsibility that the professional caregiver must take on. The patient is in an acute condition and not able to see things in a longer perspective; the patient has to endure in the present (J. M. Morse, 2001). Professional caregivers, on the other hand, have experience and theory based-knowledge and, therefore, an obligation to put the various elements in context and look at the longer term. For example, it is necessary to ensure that the patient gets good sleep right from the beginning. None of the patients in Studies I or II expressed that they, at any point during their hospital stay, had complained about annoying noise, indicating that it is the professional caregivers' responsibility to create a good care environment.

It is also important to emphasize that the patient is in a state of dependency as their survival lies in the hands of the staff and, indirectly, in the hands of the health care organization. Even if the patient had an opinion regarding their environment, it would take a lot of courage to criticize the light or surrounding noise. It is important to consider these conditions when listening to the voice of patients concerning the care environment and its significance. Furthermore, the hope of returning home quickly also reduces the patients' expectations of a good and healthy environment. The care room is seen as a temporary stop, where the goal is to get home as quickly as possible. In a qualitative study concerning patients' experiences of acute care hospital environments, patients described the hospital as "*a place where they did not want to go, did not want to be, and were always glad to leave, a necessary evil*" (Shatell, 2005, p 166). This means that the shorter the LoS, the less important the physical environment.

Furthermore, a life-threatening condition affects an individual's priorities. In a situation where their life is threatened, patients focus on survival, everything else becomes irrelevant. Patients cannot and should have to consider environmental factors that

can influence their outcome in the long term. Olausson et al (2013) express that the perception of the room changes in critical illness; it becomes an existential place, complex and multidimensional. This is in accordance with Morse & Johnson (1991) who describe how suffering from a severe illness is a process which includes several steps. The first step is described as vigilance, a stage where the patient tries to keep control of him or herself and the situation. Step two is the survival phase. The patient is trying to endure, to hold on to life. The patient cannot determine whether it is real or a nightmare. At this moment, a close relationship to family or a caregiver is important for retaining contact with reality and feeling secure. This can be vital as it has been found that both silence and sudden unfamiliar sound can create fear and feelings of abandonment. The third step is the phase where the patient tries to endure so as to survive and probably also endures the noisy environment in the ICU. He or she develops strategies to manage feelings that arise, which are often expressed in anger or tears. It is most likely in the fourth step that the patient can start to take control of his or her surroundings. Now the patient slowly realizes what has happened and tries to reach specific goals. The fifth step is to learn to live with a changed body and mind.

Sound, noise and ICU delirium

Two studies in this thesis have raised the issue of sound and noise and its relationship to ICU delirium. In Study I, which is a correlational study, no relationship between high levels of noise and early signs of delirium were identified. Since the sample was very small, the result should not be regarded as definitive, only 13 patients were included in the study. Study IV describes no correlations, only incidence. Approximately 20% were identified as having ICU delirium at some point during their hospital stay, a figure that is comparable with other studies (Girard, Pandharipande, & Ely, 2008). The idea of sound and noise as a risk factor for the development of delirium has been discussed in the literature and, while waiting for clinical studies in the field, several articles recommend noise control as a preventive measure for delirium (Barr et al., 2013b). However, to the author's knowledge, few have examined the relationship between delirium and noise in clinical interventions studies.

One study, investigating the effect of the ICU environment on the prevalence of in-hospital delirium after cardiac surgery, found no significant differences between silent private rooms equipped with physical barriers and multi-bedrooms characterized by high "traffic" noise and no windows (Arenson, MacDonald, Grocott, Hiebert, & Arora, 2013). This indicates that more research in the area is needed; however, there are several challenges to overcome. Many predisposing and precipitating factors have been identified, which may increase the risk for developing ICU delirium and this places great demands on the design of RCTs in this area. Study IV illustrates the logistical problems and challenges regarding clinical intervention studies in intensive care.

Staff knowledge concerning sound and noise

In Study III, responses to the questionnaire showed that physicians, ICU nurses and enrolled nurses in the ICU have poor knowledge when it comes to sound and noise and their effects. This result is comparable to a British study in which 96 registered nurses (RNs) responded to the same questionnaire (Christensen, 2005). No study has

previously examined the levels of knowledge of various health professionals working in the ICU regarding sound. It is alarming that staff who work bed-side, responsible for caring for vulnerable critically ill patients have such inadequate knowledge. It is true that the response rate was low, and this must be taken into consideration. However, as mentioned earlier, noise levels in hospitals have increased in recent years (Busch-Vishniac et al., 2005), and a lack of knowledge may be one of the causes. After 15 years of experience, it is the author's opinion that the ICU sound environment is not prioritized and, consequently, it is likely that these 305 respondents are representative of ICU staff in general.

There are many reasons why knowledge does not reach clinical practice, but one key factor is knowledge of the existing subject area (Grol & Grimshaw, 2003). This study did not aim to identify individuals' levels of knowledge; the purpose was to identify the state of knowledge as it is today. These results can be used for educational strategies both by universities and also by employers whose responsibility is to provide adequate knowledge and training for their staff. Even if life support actions are necessary and important, more must be done to meet the fundamental needs of the patient. Similarly, it is time to see patients as a whole in traditionally medical fields such as intensive care and to include non-medical parameters as important parts of their care.

Suggestions for improvements

In Study III, respondents made many suggestions for improvements at various levels, and the category "Improving physical space and technical design" included suggestions related to the physical environment. Two of the subcategories highlighted by the majority of the participants were sound-absorbing arrangements in the rooms and one-bed rooms for patients. Sound-absorbers were used in the rebuilt experimental room in Study IV, and bas-line measurements found lower reverberation time for low frequencies and better speech clarity. These improvements may seem trivial but, in advanced critical care communication between health professionals but also between patients and staff, they may be crucial. Building single-bed rooms was suggested by several interviewees in Study III, and one of the staff concluded that it is a logical reasoning, i.e. the more patients in a room, the more sound from the staff. Similar results were seen in an American study (Chaudhury, Mahmood, & Valente, 2006). Single-bed rooms in hospitals and ICUs have been an issue for a long time since Sweden and many other countries are in the process of building new hospitals and new ICUs. Some are reluctant to the idea, mainly for cost reasons, but also for logistical reasons (Chaudhury et al., 2006).

A recent Swedish study investigating patients' experiences of multiple-bed hospital rooms found that many patients expected to meet and share rooms with strangers (Persson & Määttä, 2012) and, thus, they developed different strategies to address needs such as privacy and integrity. However, there are only a few studies examining sound pressure levels in relation to the size of the room. In a new Swedish study, which studied relationships between noise levels, disruptive sounds, rooms of different sizes and varying numbers of beds, no difference was found between the rooms in terms of noise levels. Interestingly, however, results indicated that disruptive sounds

were nearly 40% less frequent in single-bed rooms compared to other types of rooms. Results also indicated that 64% of the sounds were avoidable (Tegnestedt et al., 2013). Most of the literature advocates single-bed rooms - not only for hygienic reasons, but also because of sound and noise (Bazuin & Cardon, 2011; Halpern, 2014; van de Glind, de Roode, & Goossensen, 2007).

Something that has not been considered as equally important and, therefore, not discussed to any great extent is the perception of critically ill and vulnerable patients being cared for with other patients. Study II, revealed that the sounds from neighboring patients could be perceived as unpleasant or even frightening. Similar experiences were seen in other studies (Engstrom et al., 2013; Karlsson et al., 2012; Samuelson, 2011; Ylikangas, 2007). Another aspect mentioned both in the literature and in Study II is the patients' need for control over their situation and their environment, something which is often lacking in hospital care (McMahon, 1994; R S. Ulrich, 2001). More studies are needed to evaluate the effects of single-bed rooms, specifically in intensive care. The new Karolinska Solna (NKS) hospital in Stockholm, Sweden, which is currently being built, will only have single-bed rooms in the ICU and the main argument has been to reduce the number of hospital- acquired infections (Solna-förvaltningen, 2011). Hopefully, the sound environment will also be developed and evaluated.

Methodological reflections

It is well known that not only can noise be measured and quantified; it can also be experienced subjectively. Therefore, it was considered necessary to illustrate this research area from several perspectives using different approaches, which required different data collection procedures and different methods of analysis. Moreover, in order to get as broad a picture of the area as possible, close collaboration with professionals with specialist skills was required, something the author believes has enriched this work. As a start to this thesis, visualizing the acoustic conditions in order to provide a fair picture of the caring environment was found to be necessary. Furthermore, the first study (Study I) was designed by a research group as a pre-study prior to a planned intervention that aimed to investigate the relationship between physiological parameters and noise levels. These sound measurements constituted an important foundation for the studies that followed.

However, sound levels alone are not enough to illuminate the area from a clinical nursing science perspective. The goal is to design the ideals for caring, to bring these ideals towards reality and the reality to the ideals. This implies that clinical care science should not be controlled by practical purposes but will contribute to the achievement of practical purposes (Eriksson & Lindström, 2003). To achieve this, a broader and more nuanced picture of the research field was required and, therefore, both qualitative and quantitative approaches were used, both within the same study (Studies I and III) and in this thesis. To allow two different approaches and traditions to coexist in the same study causes no conflict: on the contrary, they enrich one another and place the research findings in a wider context. Polit & Beck (2012) and Weaver & Olson (2006) propone paradigmatic plurality and suggest that different methods may complement one another. By being open to different methods, the method that best suits the research question can be adapted. Furthermore, quantitative findings some-

times need clarification through qualitative studies, something which is seen in Studies I and III.

In Study II, a secondary analysis of the interview data in Study I was performed, i.e., the old data were processed again on the basis of a new research question. According to Polit & Beck (2012), a secondary analysis of data is a good way to take advantage of the collected material. However, it also poses a question of resources, since the data collection process is the most expensive and time-consuming part of a study. Nonetheless, the researcher also has a responsibility to the included participants to use all the data collected.

Sampling and participants

Studies I and IV

In Study I, sound pressure levels were measured for 13 patients; however, one set of measurements was unusable due to technical problems. These twelve 24-hour periods of sound level measurements (at one-minute intervals), contain extensive data and are to be considered as very reliable for describing acoustic variables. This also applies to Study IV where noise measurements were taken continuously (at 30 second intervals).

Studies I, II and III

After discharge from the ICU, thirteen of the original nineteen patients agreed to participate in the qualitative research interview (three had died, one refused to participate and two could not be contacted) (Studies I and II). That so few were available for interview can be seen as a weakness. However, in Studies I and II, most interviews lasted 1-2 hours resulting in 103 pages of transcribed text, and this was considered to be rich material. According to Polit & Beck (2012) the choice of a particular setting determines how rich and substantive a result will be. The sample size is of importance, but they point out that even a small number of participants can generate a large amount of data for analysis. The purpose of qualitative studies is not to generalize, it is to discover meanings. Moreover, qualitative studies strive to promote an understanding of the whole of a phenomenon. It is the opposite of quantitative research, which requires a sample size large enough to achieve statistical validity and the ability to draw general conclusions from the results.

The participants in Studies I and II were of different ages and LoS, which is considered as strength since large variation was sought in this qualitative research. Moreover, since patients with different LoS and levels of illness recover differently, the patients were interviewed at different times after discharge from the ICU. This enabled participants to report different types of memories which were of particular interest in Study I. However, important information from the most severely ill may have been missed, i.e. from the three who later died, as they were unable to share their experiences. In content analysis, as used in Studies I and III, sample strategy is essential. The sample must be appropriate and include participants who are representative for the research and who can provide knowledge about the subject. Satu Elo et al. (2014) call this a purposive sampling, i.e. choosing informants who know best when it comes to researching the topic. In the study using the phenomenological hermeneutical method, the number of participants was not discussed specifically but a guiding

principle within phenomenology is that all participants must have had experience of the phenomenon and must also have the ability to express these experiences (Polit & Beck, 2012).

Study III
In Study III, physicians, ICU nurses and enrolled nurses from nine ICUs from Region Västra Götaland and region Halland were chosen. Not including staff from all ICUs in Sweden can be seen as a weakness, but the hospitals and ICUs included are considered to be representative of Sweden in general since they were comprised of university, county, regional and specialist care. Three physicians, ten ICU nurses and seven enrolled nurses participated in the interview study. The fact that only three physicians were included can be seen as a weakness and the study would have been enriched if more physicians had been able to contribute data. Physicians and nurses have different starting points in their professions and, in qualitative research, the goal is to have varied and rich material to analyze. The managers at each ICU were asked for and selected all of those interviewed in Study III. A weakness of this may be that the interview group consists of persons who were especially interested in sound and noise. However, as the voluntary participants made many suggestions for improving the sound environment, this may be seen as an advantage.

The web-based questionnaire was sent to 1047 ICU staff. However, it is important to emphasize that only 305 responded. Distributing a web-based survey is a challenge and considering the low response rate, there are several aspects that could be improved. Monroe & Adams (2012) who implemented a web-based survey with good results and a high response rate, give some advice as how to increase the response rate. One important aspect is to draw up an inventory to determine if an online survey is a viable option and if email addresses are available. To the author's knowledge, most communication between employees and management in Swedish hospitals today is carried out using e-mail. Therefore, a web-based survey was considered a good way to explore the topic. However, reading emails is not a daily task for ICU staff since they primarily work bed-side. Moreover, they do not have access to personal computer or workspace, which may have affected the response rate. Furthermore, Monroe & Adams (2012) recommend that the questionnaire should be designed so that it is applicable to the group concerned. The questionnaire in Study III was not tested in a Swedish context before it was sent out, which may be a weakness as there may be differences between countries regarding national regulations for ICU sound environments . However, the questions asked concerned knowledge about sound and its effects on human beings. Such questions could be seen as independent of nationality. According to Dillman (2000) personal and frequent contact is key to preventing a low response rate. In Study III, the questionnaire was sent to staff at the different ICUs from a body outside the hospital (the University of Gothenburg), which may have given an impersonal impression.

Study IV
In Study IV, the intention was to recruit all patients who were placed in the two intervention rooms and who stayed for 48 hours or more. As described in Study IV, thirteen patients were missed because it was not possible to staff the unit with researchers

around the clock, 7 days a week, which can be considered a weakness. It is also something that is discussed in the study where the aim was to identify factors that can be improved for the full-scale study. Similarly, six patients were missed because of technical problems, something that will also be addressed.

Validity and reliability

Validity in qualitative research

Validity is basically a property of an inference, i.e. components in the design of a study which may fundamentally affect the conclusions drawn (Polit & Beck, 2012). Whittemore, Chase, & Mandle (2001) mean that the term validity is also the proper term to use in qualitative research. Reliability refers to a measure's stability, consistency or dependability.

In this thesis, two different qualitative analysis methods have been used, content analysis and the phenomenological hermeneutical method. These methods both have strengths and weaknesses. One criticism voiced regarding manifest content analysis, used in Studies I and III, is that it is merely descriptive and that the result is usually reported without the underlying reasons or motives. Its strengths is that it focuses on the subject and context (Graneheim & Lundman, 2004). In Study I, where the aim was to describe patients' memories, manifest content analysis was considered to be a suitable method since the method's focus is on what the text says. This was also the case in Study III, where the aim was to describe various concrete suggestions for improvements. In Study II, however, the aim was to illuminate meanings and a different type of method, the phenomenological hermeneutical method, was considered to be better suited. The strength of the phenomenological hermeneutic method is in its three steps, which strengthen validity.

Whittemore et al.2(001) have described four so-called primary validity criteria useful in qualitative research, and various techniques, methods, which are useful for reducing threats to validity. *Credibility* is a central concept, also considered by Lincoln & Guba (1985), and is to be seen as the overall goal of qualitative research. It is about trusting that an accurate interpretation of the data has been presented. The result should reflect participants' experiences in a credible way. In all included qualitative studies (Studies I, II and II), the chosen methods have been described in detail, and examples from the analysis process are presented in tables. Interviewing patients who have been seriously ill and tired and, as a consequence, may not remember much can be seen as a challenge. However, in Studies I and II, patients were interviewed 2-35 days after discharge, and only two of thirteen expressed that they had no memories at all from the ICU. This is in accordance with a study in which trauma patients' memories were studied after a stay in ICU (Ringdal, 2008). Four out of five patients were found to have some factual memories months after being discharged. In Studies I and II, several quotes have been included in order to reinforce credibility. Quotes were not chosen in Study III, which may be seen as a weakness. Nevertheless, the analysis process is described in detail to enable the reader to form an opinion about the procedure.

Authenticity refers to the degree to which the researchers fairly and credibly demonstrate a register of reality. A text has authenticity if it invites the reader to a vicarious

experience of the experiences described. Satu Elo et al. (2014), who have reflected on the content analysis method and its trustworthiness, express that writing makes something disappear and then reappear in new words and in a new form. The analysis and its contents should aim to clarify the results in a way such that it has a meaning for the reader. In Studies I and III, the results have been presented as descriptively and structured as possible so as to help readers understand and familiarize themselves with the patient's experience. In Study II, so-called composite stories were chosen as a way to further help readers to understand. *Integrity* concerns honesty in the sense that interpretations should be carefully and repetitively checked. Integrity highlights elements such as the interpretations, assumptions and preconceptions of the researcher, which may influence the research process. There should be ongoing self-reflection and review throughout the research process. Although qualitative interpretive research values the investigator as a person who may interpret data uniquely, integrity is important. There should not be any doubt that the interpretation is valid and based on the existing data. In the analysis processes of Studies I and III, several researchers participated. Similarly, the research team gathered and discussed the analysis in relation to the data on several occasions. The phenomenological hermeneutic method is not only about understanding and explaining but is also about interpretation.

According to Ricoeur (1998) our pre-understanding is crucial to how we interpret and understand a text. In Study II, two researchers, the first author and a co-author, analyzed and interpreted the interview text. Both are critical care nurses and well informed when it comes to research in critical care. Moreover, both have previously worked in the ICU, which implies knowledge of the conditions and the organization. Ricoeur (1976, 1998) stresses that it is always possible to argue for or against an interpretation; there is no single unique, way to interpret a text. However, that does not mean that all interpretations are equally probable. The final interpretations presented in Studies I,II and III were assessed by the authors as being valid and credible. Finally, *Criticality* is about always having a critical attitude. Research design should consistently express that the research process and its components have been reviewed continuously. Ambiguities should be explored and recognized, and appropriate proposals to check findings should be provided. Since the research team was composed of several members, discussions with a critical approach were conducted continuously.

Validity and reliability in quantitative research

In this thesis three methods for quantitative measurements have been used; one protocol for identifying early signs of delirium, one assessment instrument for ICU delirium and a web-based knowledge questionnaire.

Regarding the identification of early signs of delirium, Study I used a protocol that has not previously been used. Based on observations conducted in intensive care, it includes twenty indicators contained in four main categories; behavior, gaze, communication and sleep. The signs or indicators are to be observed and documented every hour. The protocol should not be seen as a fully developed instrument; it is more similar to a protocol that helps RNs to assess a patient's condition. Its strength is that the observations are documented every hour, demonstrating the patient's development. Delirium fluctuates during its course and early signs can be identified at an early

stage by appraising at short intervals. However, these short intervals may also be a weakness as it is not always possible for RNs to appraise twenty signs 24 hours a day. Another strength is that the signs can identified without the patient's participation, meaning that the protocol can be used around the clock.

The CAM ICU instrument was developed and tested by Ely et al. (2001) and was translated, retranslated and validated in a Swedish context by Larsson et al. (2007). Moreover, in the same study, inter-rater reliability (two persons completed the instrument independently) was calculated and found to be high. However, measurements of ICU delirium were taken only once a day in Study IV and, therefore, any fluctuation in delirium during the day may not have been recognized.

The knowledge questionnaire used in Study III was developed and tested in a British context by Christensen (2005). To my knowledge, this instrument has only been used once. Christensen (2005) tested content validity by allowing a five-member group to review the questionnaire on two separate occasions, prior to and after a pilot study. After the pilot study, which included twenty ICU nurses, the instrument was further refined, and the final design was considered practical, reliable, measurable, usable and valid. No validity tests were conducted in a Swedish context before distribution, which can be seen as a weakness.

CONCLUSIONS

- Sound pressure levels inside the ICU patient room are higher than existing international and national guidelines.
- Patients cared for in the ICU hear and are aware of the ambient sounds during their stay despite their fatigue and critical illness. Patients recall those sounds afterwards and can describe the character of the sounds and noises and their experiences of them.
- Being seriously ill and cared for in the ICU means never being able to be prepared for the ambient sounds, they come suddenly and unexpectedly, from different directions and in different intervals and strength, making the patient feel constantly on edge.
- ICU staff have poor knowledge when it comes to sound and noise and its health effects.
- It is possible to improve the noise environment in the ICU patient room and suggestions from staff include actions on three levels: improvements on an individual level, improvements that require collaboration between individuals, groups and instances, and improvements where external agencies need to be consulted.
- It is possible to implement a complex sound intervention study in intensive care.

Clinical implications

The sound environment in the ICU patient room is complex, which means that there is no single simple solution to the problem. Nevertheless, the findings in this thesis provide several opportunities. The most valuable one is that the patient's voice has been heard. Many new intensive care units and hospitals are currently being built, and these narratives can be used as a basis for the design of future health care environments. Moreover, if tomorrow's health care environment is to be caring and curative, a holistic approach is needed. Therefore, the findings in this thesis suggest that resources should also be invested in other areas besides the medical, including influencing sound and circadian rhythm. Furthermore, staff knowledge and attitude are of importance for the sound environment. In order to meet the patient's needs, an understanding of the patient's situation is needed. An understanding of the patient's situation can also develop and generate caring acts. For a long term and lasting change to occur, education both in the clinic and at universities is required, for all professions and levels. Finally, concrete suggestions for improvement from staffs can be used for future interventions. If the measures are grounded with staff, there is a greater potential for creating sustainable care environments in intensive care.

FUTURE RESEARCH

- In a full-scale RCT, study the relationship between noise levels and the development of delirium.
- Develop guidelines for improvements based on staff suggestions and then evaluate implementation in an intervention study
- Identify and examine existing barriers to improving the sound environment
- Using a qualitative approach, explore the meanings of working as a nurse inside a sound- intensive ICU patient room.
- Examine how patient safety is affected by the sound-intensive environment in the ICU patient room.
- Implement and evaluate educational programs concerning sound and noise and their health effects.
- Study the effects of the sound environment on patients' sleep patterns and how they regain their normal sleep patterns.

SVENSK SAMMANFATTNING

Inom intensivvården vårdas de allra mest svårt sjuka och skadade patienter inom somatisk vård och varje år vårdas ca 45 000 personer på intensivvårdsavdelningar (IVA) runt om i Sverige. Intensivvården karakteriseras av en hög bemanning, omfattande övervakning av fysiologiska parametrar och behandlingar som pågår dygnet runt. Det innebär att ljudmiljön runt patienten både är komplex och krävande. Tidigare forskning visar att ljudnivåerna inne i patientrummet på IVA är betydligt högre än befintliga rekommendationer och ingen förbättring har skett de senaste åren. Det är anmärkningsvärt, eftersom patienter som vårdas inom intensivvården är sköra och utsatta och därmed i behov av en miljö som stärker individens resurser och medverkar till återhämtning. I den här avhandlingen argumenteras för att kvaliteten på patientens vårdtid är av stor betydelse, både för patientens välbefinnande under vårdtiden men också när det gäller tillfrisknande. För att förbättra vårdmiljön och därmed vårdkvaliteten krävs ett humanistiskt synsätt, det vill säga att patienten ses som en unik person med många vitala mål och behov.

Tidigare studier har visat att buller och störande ljud har en negativ effekt på människors hälsa; påverkan på hjärtrytm och tarmmotorik är några negativa effekter som nämnts, men mer forskning behövs, framför allt när det gäller effekter vid kritisk sjukdom. Sömn i relation till buller är det område som studerats mest. Även om det inte är klarlagt i hur stor omfattning ljud och buller påverkar sömn vid kritisk sjukdom, vet vi idag att patienter som vårdas på IVA sover dåligt och att de har ett försämrat sömnmönster. Vårdmiljön och dess utformning, inklusive ljud och buller, bör därför ses som en del av vården och vårdandet. I framtiden kan nedsövda patienter inte längre vara en förevändning för att tillåta en bullrig och undermålig ljudmiljö i patientrummet på IVA. Enligt den Svenska Hälso- och sjukvårdslagen är vi som arbetar inom hälso- och sjukvård skyldiga att tillhandahålla en god vård. Det finns därför ett stort behov av att utveckla kunskap kring vad god vård står för, vad det är som bidrar till en god vård och identifiera eventuella hinder.

Det övergripande syftet med den här avhandlingen har varit att belysa hur svårt sjuka patienter upplever att vårdas omgivna av ljud och buller. Vidare har syftet varit att undersöka personalens kunskap om ljud och buller samt identifiera förslag på förbättringar, liksom att undersöka möjligheterna att utföra en komplex interventionsstudie med kontinuerliga ljudmätningar inom intensivvård.

Forskningsområdet är komplext och behöver belysas från flera perspektiv. Metoder från olika forskningstraditioner har därför använts och studier med såväl kvantitativ som kvalitativ ansats har inkluderats. Vidare återfinns studier med beskrivande design men också jämförande analyser. En studie är en del av ett interventionsprojekt, en så kallad feasibility-studie, och innefattar observationer.

I två studier mättes ljudnivåer inne i patientrummet på IVA. Mätningarna visade ljudnivåer betydligt högre än gällande riktlinjer; de ekvivalenta ljudnivåerna motsvarade nivåer vid en trafikerad väg. Eftersom ingen studie tidigare har frågat patienter som

vårdats på IVA specifikt angående deras upplevelser av ljud och buller på IVA, intervjuades 13 patienter efter utskrivning. Resultatet visade att patienterna mindes många ljud och kunde beskriva dessa, ljuden kunde vara av positiv såväl som negativ karaktär. Patienterna mindes ljud från omgivningen, från personalen, från patienterna i samma rum och ljud från teknisk utrustning. Vidare beskrev patienterna upplevelsen och innebörden av att vårdas i ett ljudintensivt rum. Patienterna beskrev att ljuden kom oväntat och plötsligt, vilket innebar att de aldrig kunde förbereda sig eller värja sig. De kunde uppleva en känsla av trygghet när ljuden gav information om att man var väl omhändertagen, men ljuden kunde också upplevas som skrämmande och skapa känslor av rädsla och hjälplöshet.

En web-enkät med frågor om ljud och buller och dess effekter skickades till läkare, specialistsjuksköterskor inom intensivvård och undersköterskor vid nio intensivvårdsavdelningar i Västra Götalandsregionen och Halland. I resultatet sågs att vårdpersonalen som arbetar nära patienten på IVA har en mycket låg kunskap när det gäller ljud och buller och dess negativa effekter på människan. Vidare så intervjuades 20 läkare, specialistsjuksköterskor inom intensivvård och undersköterskor från samma intensivvårdsavdelningar och ombads komma med förslag på förbättringar. Personalen gav många förslag och menade att åtgärder måste vidtas på flera nivåer för att någon förbättring ska ske. Dels föreslogs åtgärder som den enskilde vårdaren kan göra under sitt arbetspass, t ex justera larmgränser, koordinera vårdaktiviter och erbjuda öronskydd. Vidare föreslogs åtgärder där individer och grupper på avdelningen måste interagera och samordna, t ex organisera vilostunder för patienterna under dagtid eller involvera arbetsledningen. Slutligen gavs förslag på åtgärder som gällde den fysiska miljön.

Eftersom endast ett fåtal studier har undersökt effekter av ljud och buller på svårt sjuka patienter, planerades en större jämförande interventionsstudie inkluderande kontinuerliga ljudmätningar. Det innebar att ett två-bädds patientrum på IVA byggdes om och utrustades med ljudabsorbenter, ett nytt ljussystem och ny estetisk utformning. Ett likadant två-bäddsrum behölls i originalskick. Med syfte att undersöka om det är möjligt att genomföra en fullskalig studie, samlades data in från dessa två rum under en 7-månaders period. Forskningsprocessens alla steg observerades fortlöpande samtidigt som hinder identifierades och förslag på förbättringar utvecklades (så kallad feasibility-studie). Studien visade att en intervention ute i klinisk verksamhet, där man har som mål att mäta bullernivåer och relatera dessa till en fysisk parameter, är ett komplext och resurskrävande arbete men möjligt att genomföra.

Slutsatsen är att ljudmiljön på patientrummet på IVA är undermålig och att något måste göras för att förbättra detta. Patienterna minns ljuden och upplever dessa i många fall som obehagliga och okontrollerbara. Personalen som arbetar nära patienten har låg kunskap i området och därför behövs utbildning för att lyfta medvetenheten. Däremot har personalen många idéer om hur miljön kan förbättras. Fortsatta studier behövs för att utforska om det finns ett samband mellan fysiologiska negativa effekter och ljud och buller på IVA men interventionsstudier i den här miljön är komplexa och resurskrävande.

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