How Noise Affects Patients in Hospitals

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Hospitals are where patients stay to improve their current condition and well-being. However, many studies demonstrate that noise has negative effects on patients during their hospital stays. Results from these studies show that areas such as sleep quality, speech processing, and various physiological functions are influenced by noise exposure. Most of the noise exposure that causes disturbances to the patients are generated by the staff and machines. This paper describes and discusses noise pollution in hospitals so that appropriate countermeasures can be applied to reduce noise. In addition to research on noise reduction strategies, recommendations regarding the improvement of human factors, such as staff training and hospital design, are discussed.

INTRODUCTION

Noise, which is a type of sound, is unwanted perceived acoustic information. It is typically measured on an A-weighted decibel (dB(A)) scale, which is the measurement of energy that is found in noise compared to the "minimum amount of energy that the average human can detect" (Hsu et al., 2012, pp.301). Humans encounter noise in their daily lives, even when it is perceived to be quiet. However, when exposed to too much noise, it can be detrimental to one's hearing and processing. For those who work in noisy conditions, a temporary threshold shift can occur in which there is a short period of hearing loss after the noise exposure. Although the ear will recover over time, exposure to intense noise for a long period of time may result in a permanent threshold shift, from which it is harder to recover (Wickens et al., 2004). Thus, appropriate regulations have been put into place to ensure safe environments for all workers. For the United States, Occupational Safety and Health Administration (OSHA) was created to ensure safe conditions for all workers in their working environment. This includes guidelines for daily allowable dosage amounts and duration of noise (Wickens et al., 2004).

In addition to workplaces, the hospital is also a space where people are most exposed to noise. From machines that help monitor patients to conversations between the nurses, patients are constantly exposed to noise. Studies have shown that noise is one of the main factors that cause disruption to patients during their stay (Delaney et al., 2018). Similar to regulations placed on workplaces, the World Health Organization (WHO), an international organization that helps manage international health within the United Nations' system, has provided recommendations for noise levels within the hospital ("About WHO," 2018). Although these recommendations are put into place, many hospital settings fail to stay within the appropriate range of noise.

GOAL OF PAPER

The objective of this paper is to bring awareness to the various ways that noise can influence how patients in hospitals are affected by noise. This work further seeks to discuss how better human factors, such as environmental design or training, can be implemented to ensure a more-nurturing environment.

NOISE LEVELS

The noise levels in hospitals have become an increasing problem over the years (Morrison et al., 2003). Within intensive care units (ICUs), noise has been suggested to be the most bothersome stressor for patients (Delaney et al, 2017). The WHO recommends that the average noise in hospitals should not exceed 35 dB(A) (Padmakumar et al., 2013). Additionally, the WHO recommends that noise levels should not exceed 30 dB(A) during the night (Delaney et al., 2017) and 40 db(A) during the day (Akansel et al., 2008). However, studies show that despite these recommendations, noise levels in the hospitals go well beyond those levels of dosages. As a result, patients experience negative consequences from noise exposure. Within the hospital, there are combinations of different noises to which patients are exposed. These include noises generated by people and machines.

People-Related Noises

People-related noises were found to be the main cause of disturbance (Akansel et al., 2008). Conversations were reported to be the most disruptive, as shown in Figure 1, among all the other sources of noise (Allaouchiche et al., 2002). Conversations amongst the staff were found to be responsible for 56% of the peaks above 65 dB(A) (Allaouchiche et al., 2002). Additionally, as background noise in the hospital increases, it requires people to amplify their speech to compensate for the surrounding noises (Padmakumar et al., 2013). This effect is known as the Lombard effect and, as a result, intensifies the overall noise of the hospital's environment (Delaney et al., 2017).

These findings suggest that workers in the hospital have a huge influence on the amount of noise that disturbs patients. For example, a study shows that the number of workers during the 8 a.m. to 4 p.m. shift contributed to much of the noise reported during the day. Patients reported the most disturbance during that time because there were more workers tending to patients, switching out equipment, and making routine check-ins with patients (Akansel et. al.,2008).

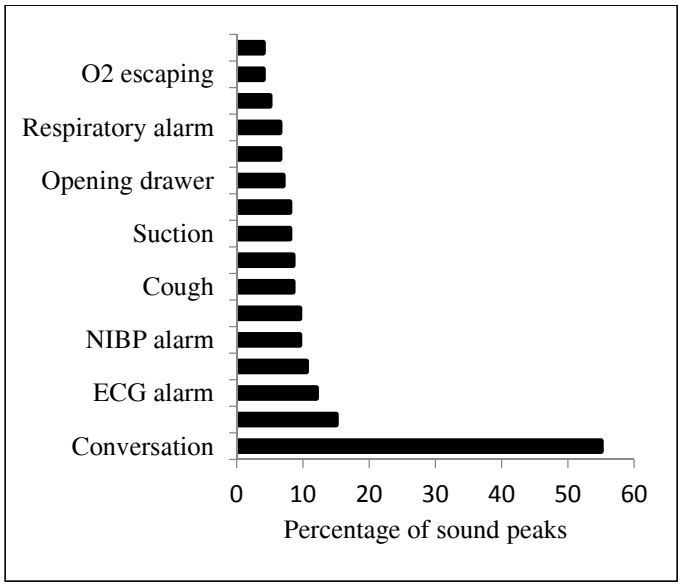

Figure 1. Summary of noise levels found during study (values in percentages) (Data from Allaouchiche et al., 2002)

Equipment Noises

Machines within the hospital are also a contributing factor of noise to which patients are exposed. In one study, it was found that much of the noise was attributed to the alarms from machines such as the non-invasive blood pressure (NIBP) and electrocardiogram (ECG) devices (Allaouchiche et al., 2002). However, findings suggest that most of the disturbances from machines can be prevented with better attentiveness. Studies found that many of the alarms that went off were false alarms, which exceeded dosage levels of 70 dB(A), which is equivalent to noise conducted by traffic, such as car engines or car horns. (Akansel et al., 2008; Delaney et al., 2017). Furthermore, patients reported monitor alarms as the most disruptive (Akansel et al., 2008). However, because machines and devices are vital in monitoring a patient's health, patients are, as a result, constantly exposed to noise.

CONSEQUENCES OF NOISE

Noise not only creates disturbances for patients. It can also affect the ways that they recover from their injuries, cognitively process, and mentally perform.

Sleep

Sleep is an important factor in aiding patient's recovery and energy for their treatment. Sleep mainly consists of two phases: non-rapid eye movement (NREM) and rapid eye movement (REM) sleep (Delaney et al., 2015). NREM has three stages that make up around 75% to 80% of a person's total sleep time. After cycling through the 3 stages of NREM, a person moves into REM sleep, which makes up around 20%-25% of their total sleep time (Delaney et al., 2015).

Studies conducted as early as 1976 examined the quality of patient's sleep in ICUs using polysomnography and electroencephalography devices (Hsu et al., 2012). Hsu et al. conducted a study with ten patients who were exposed to various noises such as "alarms, phones, ventilation, and machine noise (2012, pp.303)." The results showed that none of the patients were able to have an uninterrupted sleep cycle. Thus, many patients end up staying within the first two stages of NREM sleep, which is considered light sleep (Delaney et al., 2015). Because patients lacked sufficient sleep in REM, there are a limited amount of restorative benefits, which ultimately affect their recovery rates (Delaney et al., 2015). Furthermore, it is shown that patients experience sleep disruptions of around 11% to 20% of the time because of noise (Hsu et al., 2012). These studies provide evidence that noise has a direct influence on the quality of sleep received. Not only does it decrease energy levels throughout the day, but also, sleep deficits can affect cognitive factors, such as "memory retention and learning capabilities" (Hsu et al., 2012, pp.302).

Additionally, sleep deficits can result in negative physiological effects for patients (Delaney et al., 2015). The sleep cycle is controlled by a 24-hour biological clock, which also regulates circadian rhythms (Padmakumar et al., 2013). The clock also helps control physiological and behavioral rhythms, such as "body temperature, immune function, hormone secretion, and muscle tone." Thus, lack of sleep can affect the maintenance of circadian rhythms, which is important for physiological well-being (Padmakumar et al., 2013).

During the studies, patients were reported to experience waking and arousal from sound pressure levels of 50 and 60 dB(A). Table 1 shows the different sources of noise that patients experience, which demonstrates that patients are constantly exposed to noise levels of at least 80 dB(A) every hour. This further suggests that disruptions in sleep occurred frequently.

Source	Mean occurrences in dB(A) per hour mean (SD)	Proportion of total occurrences per hour (%)
Staff	84.38 (32.77)	35.5
Alarms	81.06 (43.95)	34.1
Other	35.81 (19.96)	15.1
Doors	12.88 (12.37)	5.4
Pumps	7.19 (12.55)	3.0
Equipment	6.06 (4.64)	2.6
Trolleys	5.94 (7.19)	2.5
Wash basins	4.13 (2.55)	1.7

Table 1. Different nocturnal noises to which patients are exposed per hour in ICUs. (Data from Delaney et al., 2017)

Studies also show that a lack of sleep causes a decline in patient respiratory muscle strength and brings about hypoventilation. This causes a slower breathing rate and slows

a patient's ability to stop relying on a machine for ventilation. As discussed earlier, equipment is a factor of noise exposure, so any opportunity to lessen machine use will help reduce noise exposure. Furthermore, sleep deprivation can also affect the immune system and the rate of recovery for patients. Neuro-immunological research suggests a bidirectional relationship between lack of sleep and immune system health (Delaney et al., 2015).

Physiological Effects

In addition to sleep, noise largely influences physiological functions in patients. A study by Hagerman et al. found that with a higher acoustical noise exposure, patients experienced a higher pulse rate, which increased the possibility of "readmission into the coronary care unit" (Delaney et al., 2017, pp.5). Furthermore, noise can create a response in the sympathetic nervous system, which increases cardiac stress and impacts respiratory muscle function (Padmakumar et al., 2013). A time-series regression was conducted on noise levels with heart rate and blood pressure, providing more evidence that noise has an impact on physiological functions (Hsu et al., 2010). Hsu et al. found that an increase of noise created a positive correlation with heart rate and blood pressure (2010).

To further examine the effects on heart rate, Hsu et al. observed 25 patients for their heart rate, frequency of arrhythmias, and anxiety with noise levels (Hsu et al., 2012). The patients were exposed to one-minute noise recordings during two different time periods throughout the day. After these sessions, it was shown that anxiety and the number of ventricular arrhythmias drastically increased during the time that patients were exposed to noise (Hsu et al., 2012). Furthermore, a study was conducted to research the influence of noise reduction on heart rate. Hsu et al. also found that patients who did not have "absorptive acoustical ceiling tiles" placed in their rooms experienced an increase of heart rate (2012, pp. 304). The absorptive ceiling tiles were also found to decrease noise by "5–6 dB in the patient rooms" (Hsu et al., 2012, pp.304). It was also found that during conversational noises, heart rates are three beats per minute faster (Hsu et al., 2012).

Although few studies have been conducted on gastric activity, it is important to take into account its relevance with noise exposure. In a study conducted with 21 male patients, they were exposed to different noise sources with levels of 87.4, 91.3, and 85.6 dB(A). To measure gastric activity, researchers used an electrogastrogram to study gastric myoelectrical activity (GMA), which "controls stomach motility" (Hsu et al., 2012, pp.305). For the average human, a GMA of three cycles per minute (CPM) is common. However, it was found that noise exposure from the hospital and traffic in particular decreased the rate of CPM. From this, the authors concluded that noise exposure could indeed have an effect on gastric activity (Hsu et al., 2012).

Stress

Noise exposure can also lead to increased stress levels for patients (Padmakumar et al., 2013). In another study, it is suggested that noise can activate stress hormones, which affect synthesis and metabolism in humans (Hsu et al., 2010). Pain levels were also monitored, and it was found that the amount of pain medication requested by patients was related to the level of noise exposure (Hsu et al., 2012). These findings provide evidence that there are many negative physiological effects from noise, including decreases in overall well-being and impacts on the process of recovery. To provide more evidence, one study was conducted to observe the duration of patient's stay in hospitals. The study compared the duration of a patient's stay with the noise from construction in the hospital. It was found that the patients who were in the hospital during construction stayed longer than those who were admitted in periods without construction (Hsu et al., 2012).

Speech and Cognitive Processing

A paper written on the impact of noise on patients and staff in the healthcare setting concluded that noise contributed to negative processing effects experienced by patients, such as lack of clear communication and speech (Pope et al., 2013).

The clarity of speech is influenced by pronunciation, the distance between the people talking, and the "sound level of interfering noise" (Pope et al., 2013, pp.229). Noisy environments reduce the ability to distinguish speech for those who have diminished hearing capability. As mentioned before, the Lombard effect occurs, causing people to raise their voice to account for the background noise. However, in doing so, the clarity of the speech decreases, further affecting the quality of the speech itself. A general level of sound pressure is around 60 dB(A), and background noises of 45 dB(A) or greater will affect communication (Pope et al., 2013). As many studies have shown, background noises in hospitals frequently exceed the 45 dB(A) amount.

Cognitive tasks are also influenced by exposure to noise. Studies have found that noises can be stimulating for performance during simple tasks but can impede performance for more-complex tasks. Furthermore, Pope et al. observed the speech understanding and recall of participants through a "target speech stimuli exercise" (2013, pp.230). The exercise consisted of patients listening to sentences that varied from high-context to low-context sentences. High-context sentences contained information that allowed participants who were carefully listening, to be able to guess the final word. However, low-context sentences did not provide that information. In addition, these sentences were played with hospital noises in the background. To observe possible correlations between noise level and recall performance, three levels of hospital noise were presented to the patients, the lowest level being 59 dB(A) and the highest of 69 dB(A). Additionally, the sentences were played with quiet conditions (no background) and background white noise. The patient's

goal during the exercise was to remember the last word that they heard in all of the sentences.

Figure 2 shows the results from the study, demonstrating that noise levels do interfere with clarity of speech and communication (Pope et al., 2013). In this study, patients had better performance in correctly identifying words in the quiet conditions or lower noise volumes. In addition to noise level, the context provided in the sentence also affected accuracy in identifying words.

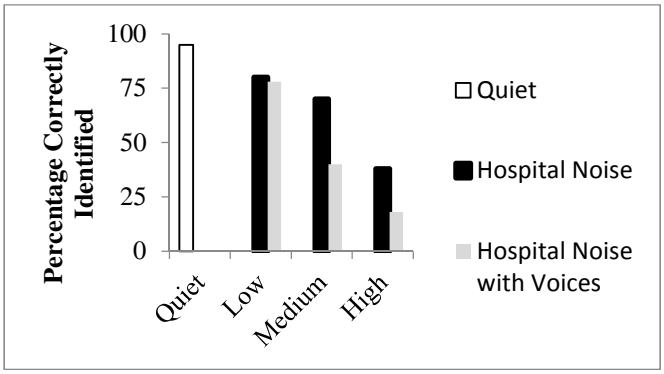

Figure 2. Results from study showing better performance in quiet environment. (Data from Pope et al., 2013).

This study also indicates that patients have a harder time hearing and processing new information in the noisy environment of a hospital. This brings up the issue of patient health after discharge from the hospital. In a study conducted with older individuals and their auditory processing, it is shown that context and a "familiar frame of reference" aids them in processing information (Pope et al., 2013, pp. 237). Thus, as patients are given information about details they need to remember, the noisy environment and lack of familiar frame of reference interferes with their memory and recall of the information later (Pope et al., 2013). Additionally, as results showed with the sentence exercise, patients are less inclined to correctly recall words for low-context sentences in addition to noise exposure. In addition, because the information relayed from hospital staff to patients usually consist of unfamiliar terms, it is crucial for patients to be able to accurately process what they are told. With a noisy environment and without much context, a patient's ability to correctly understand and process information is decreased.

DISCUSSION

Overall, it was made clear through the various studies that the noise levels in many hospitals exceed the WHO's recommended dosage. Because hospitals are supposed to be a place to foster well-being and recovery, it is important to be aware of the factors that negatively influence noise levels.

The main cause of negative impacts from noise exposure was people-related noise. This ranged from nurse conversations to patient-conducted noises. Additionally, machines created disturbances. However, much of these concerns can be remediated through better awareness from staff in the hospital. Studies have also provided evidence that patients have been negatively affected by noise. These effects include declines in sleep quality, cognitive processing, speech, and overall physiological well-being. It was found that the mean noise level in the hospital was consistently 59-60 dB(A) for different periods throughout the study, exceeding recommended dosage levels (Hsu et al., 2010). As a result, patients are constantly affected by and exposed to noise. With more evidence and knowledge of these effects, it is important for hospitals to take appropriate measures to promote a healthier environment.

Recommendations

To address the issue of people-related noise, trainings should be regularly implemented for workers in the hospital to promote better awareness of the consequences of noise. Kahn et al. (1998) led a staff training for ICU staff that discussed the implications of noise pollution and patients in the hospital. Some of the issues discussed were the effects of talking, alarms, and the intercom system (Padmakumar et al., 2013). As a result of this training, there was improvement to the noise level in the hospital. Additionally, hospitals should seek to conduct surveys or questionnaires with patients to determine what sources cause the most noise. This information can then be used to better manage and implement strategies to decrease the amount of noise exposure. Implementing signs is another way to remind staff to lower their volume during conversations. This can help with reducing disturbance for patients from side conversations among the staff (Akansel et al., 2008).

As for the equipment within the hospital, better implementation of paging devices should be applied, such as using them on a silent vibrate mode or using individual alarms instead of overhead intercoms (Padmakumar et al., 2013). This may help to decrease the noise disturbance for patients. Additionally, to combat the alarms that are left unattended, an additional feature of using tactile stimuli can be implemented to individual alarms to aid quicker response to alarms (Wickens et al., 2004). Cobus et al. proposed the idea of implementing a head-mounted wearable device that contains audio, visual, and vibrotactile cues that will alert the staffer (2017). This will help to alleviate excessive noise as the alarm will be directed to a specific staffer who is responsible for the patient, instead of the whole floor.

Lastly, better design of the space for patients within a hospital is recommended. In the study conducted by Hsu et al. sound-absorptive ceiling tiles were placed in rooms that decreased reverberation time, the time it takes for noise to decay, and ultimately helped reduce noise (2012). Furthermore, it would be beneficial for hospitals to account for more noise-reduction materials such as "double-glazed windows, floors, and walls" (Hsu et al., 2012). Additionally, it would be helpful to use materials with strong noise-absorbing abilities to help minimize the echoing of noise from activities outside the room. Although it may be difficult to design for the complete reduction of noise because the amount of space within a hospital is increasingly demanding, it will still be

helpful to take into account the placement of patient beds. This will help alleviate some noise disruption from neighboring patients and conversations from their visitors. Alongside the placement of beds, better placement of patients will also aid in reducing consequences from noise. For example, placing patients with more-critical conditions in rooms with more noise protection can help further recovery.

Noise continues to be a problem, and even with all of the research conducted, not enough has been done to combat the consequences. Awareness to noise, as well as other factors such as light, is critical to ensure the best quality and type of care for patients. Thus, knowing the consequences of noise on patients should lead to crucial measures for making more human-factored improvements in the hospital.

Limitations

Although many results of studies show the effects of noise on patients in the hospital, there are some important factors to take into account. For example, patients who had experience working in noisy conditions (at least 5 years) did not report as much disturbance to noise as the ones who did not have the same work experience (Akansel et al., 2008). Additionally, patients who have not been admitted in the ICU reported more annoyance with noise than those who have been admitted to the ICU (at least twice). Furthermore, different studies conducted research on hospitals with different layouts, making it hard to conclusively compare results.

Future Research

In addition to identifying the consequences of noise on patients, it may be important to research the implications on the workers in the hospital. Little research has been conducted on the effects of noise with hospital staff, but their well-being is equally important. Improving and accounting for the effects of noise on nurses can also improve overall care for the patients. Jenkins et al. conducted a study with anaesthetists and the noise levels in an obstetric theatre (2015). They found that high noise dosages created distractions for the staff and affected the performance of doctors during procedures (Jenkins et al., 2015). Another area that is understudied are the ways that noise affects the informal caregivers of the patient, such as their families or friends. As they often frequent the hospital to visit or take care of the patient, they are also subject to the noise and impacted by its' exposure. Thus, improving noise exposure will enhance a safer and healthier environment for all. Because many hospitals share the vision of ensuring top-quality care, making steps towards eliminating the critical consequences of noise will help to achieve that goal.

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