The Intervention of Digital Noise Display Reduces Noise Levels and Raises Staff's Awareness in Hospital Ward. A Qualitative Literature Review.

Authors
Carlos Aparício[1] and Francesca Panin[2]

1 Faculty of Health, Education, Medicine and Social Care, Anglia Ruskin University, Cambridge, UK
2 Faculty of Science and Engineering, Anglia Ruskin University, Cambridge, UK

Corresponding author
Carlos Aparício, MSc, BSc (Hon), DipHE, RN
Faculty of Health, Education, Medicine and Social care
Young Street – CB1 2LZ
Cambridge (UK)
Email: ca683@pgr.aru.ac.uk

Abstract

Background: Hospital wards are noisy environments, and this is recognised as a global healthcare challenge. Noise can reduce staff performance and disrupt patients' sleep thus delaying the recovery that led to longer hospital stay and increase risk of acquired infection. Some studies have used Digital Noise Display devices to alert the staff to reduce noise. But the literature on this topic remains heterogeneous for methods and outcomes. This systematic review aims to summarise the evidence from previous studies that utilised DND devices as the primary intervention to reduce ward or unit's noise level.

Method: The search was conducted via three databases: CINHAL, MEDLINE, PubMed and, manual harvesting through the references. As a result, 1,110 articles were obtained from the databases. Limiters, as shown in Figure 1, were applied to the initial search results. An additional six articles were included from manually searching the references, leading to 517 articles. Following a process of screening the title and abstract of the studies, reduced the data set to 156. Finally, nine articles were included in the review after full-text articles were assessed for eligibility.

Result: This review used thematic analysis to synthesise the study findings. Similar themes extracted from each study were grouped to form new themes (Aveyard et al., 2016). As a result, two new themes emerged: First, “DND reduces hospital noise levels”, and second “DND raises staff’s awareness of noise levels”.

Conclusion: The introduction of DND for noise reduction in hospital settings to improve patients’ sleep is achievable. All studies included in this review have provided evidence that DND intervention can reduce the noise between 2dB(A) – 3.6dB(A). However, the claim that DND raises staff awareness is only hypothetical at this point. There is a lack of evidence to support the claim. A further study exploring the participants’ experiences when exposed to DND intervention is necessary to understand how the intervention influences behaviour changes or raises awareness.

Keywords: Noise reduction, hospital noise, noiseguide, SoundEar, noise meter, sound meter.

Conflict of Interest

None

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Introduction

Providing care to patients in the hospital is holistic. It is not merely to provide the best available care but also requires a conducive environment that enables patients to sleep well (Broom et al., 2011; Campbell et al., 2012). Previous studies on the sleep and recovery process found that patients who slept well have faster recovery from their illness or surgery (Dobing et al., 2017; Patel et al., 2014). Hence, it is crucial to minimise disturbances to sleep (Boehm and Morast, 2009) by reducing noise in the unit (Dobing et al., 2017; Patel et al., 2014).

However, recent studies have shown that the hospital environments are often noisy and far from conducive for sleeping (Goeren et al., 2018; Guisasola-Rabes et al., 2019). The unconducive environment has contributed to poor sleep quality in hospitalised patients (Dobing et al., 2017; Patel et al., 2014). Consequently, patients' recovery from their illness is delayed. They will stay in the hospital ward longer (Goeren et al., 2018), potentially increasing their risk of hospital-acquired infection (NHS Improvement, 2018). For staff, a noisy environment can contribute to annoyance (Terzi et al., 2019; WHO 2009), a distraction to concentration, low performance (Engelmann et al., 2014), as well as communication interference in decision making (Graneto and Damm, 2013).

Hospital environment noise is now increasingly recognised as a global healthcare challenge. For the last two decades, there have been increasing numbers of research studies focusing on sleep promotion strategies by reducing environmental noise in hospital settings (Delaney et al., 2018; Eliassen and Hopstock, 2011). The most researched topic in this field is noise reduction intervention by targeting behavioural modifications. However, regardless of the success of the intervention, the problem of a noisy environment persisted (Aparício and Panin, 2020).

One aspect of noise reduction intervention in hospital settings is using Digital Noise Display (DND) to raise staff awareness and reduce noise. In this review, DND refers to all digital devices that have been used for noise reduction interventions in hospital settings. DND picks up noise levels and converts them into visual displays warn staff, visitors and patients regarding the fluctuation of noises (Plummer et al., 2019). The fluctuation is represented by colours: red is too noisy, amber warns of the increase of noise and green being quiet and conducive to support sleep. The examples of DND includes SoundEar-I (Wang et al., 2014; Engelmann et al., 2014), SoundEar-II (Guisasola-Rabes et al., 2019), SoundEar-III (Plummer et al., 2019), SoundEar-Pro (Guerra et al., 2018) Noise-Sensor-Light Alarms (Chang et al., 2006; Jousselme et al., 2011), Sound-Level-Alert Monitor (Hogan and Harvey, 2015), and Yacker-Tracker-Visual Reminder (Walker and Karl, 2019).

This review is the first study to collate noise reduction interventions that successfully used the DNDs to reduce the noise level in hospital settings. Hence, this literature review provides a critical evaluation of the evidence from DND interventions for noise reduction and staff awareness and behaviour.

Aim

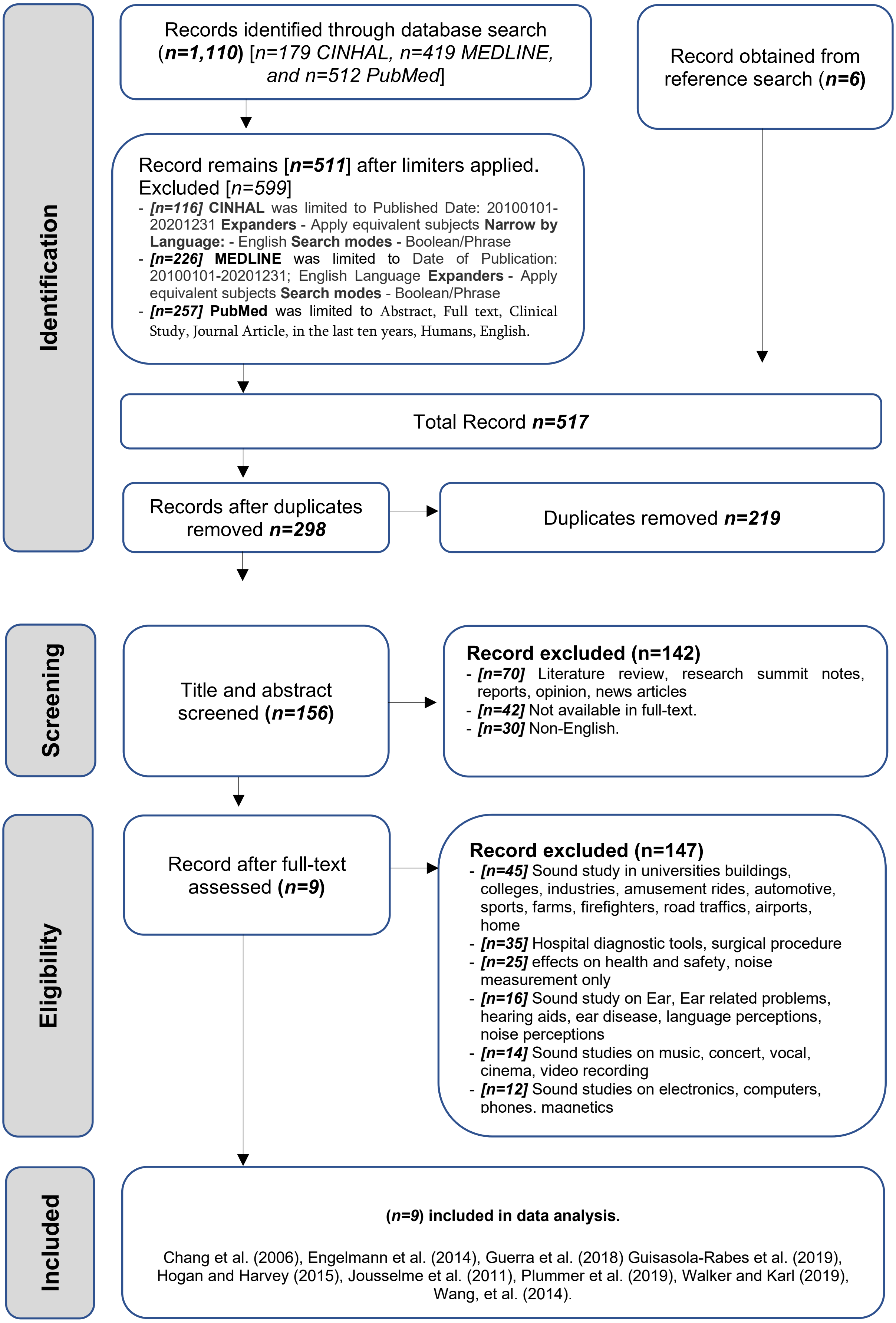
This systematic review aims to summarise the evidence from previous studies that utilised DND devices as the primary intervention to reduce ward/unit's noise level.

Methods

A systematic literature review method is used to examine the evidence from published literature on DND interventions to inform clinical nurses of the importance of noise reduction. In doing so, this literature review is guided by the question, "Does DND interventions reduce the noise level in hospital settings?"

The question was formulated using PICO [Population, Intervention, Comparison and Outcome] search strategy. PICO is a recommended tool in systematic qualitative reviews to find articles because PICO has greater sensitivity and specificity for every database (Methley et al., 2014). In this review, the population [P] is the staff and patients in hospital wards, the intervention [I] is the use of DND. The comparison [C] is no activities or comparator; the outcome [O] is noise reduction. The synonyms and the associated words of the DND were used to formulate search terms.

Figure 1: PRISMA for Literature Selection Moher et al. (2009)



The search was conducted via three databases: CINHAL, MEDLINE, PubMed and, manual harvesting through the references. As a result, 1,110 articles were obtained from the databases. Limiters, as shown in Figure 1, were applied to the initial search results. An additional six articles were included from manually searching the references, leading to 517 articles. Following a process of screening the title and abstract of the studies, reduced the data set to 156. Finally, nine articles were included in the review after full-text articles were assessed for eligibility (Aveyard et al., 2016).

Inclusion and Exclusion Criteria

This review included all primary studies in hospitals settings using DND as the primary interventions for noise reduction, published in English and within ten years span [2010 – 2020]. We excluded: (a) DND interventions in factories, offices and educational [class room] settings, (b) literature reviews and non-research studies such as authors perspectives, expert opinions, news articles, research summits and reports, (c) studies that focused on hospital diagnostic tools, ear-related problems and sound studies and (d) non-English studies.

Quality Assessment

The majority of studies included in this review consisted of quasi-experimental methodologies. The difference between quasi-experiment and actual experiments is in the participants' assignment and the use of control groups. The participants' assignment is random in an actual experiment, and it requires a control/treatment group. Compare to quasi-experiment, participants assignment is non-random and does not require a control group (Creswell, 2014, Bowling 2014). In this review, seven out of the nine studies selected utilised clinical trial methods without a control group. Therefore the assignment of wards/units to either intervention or control was not randomised. In addition, there were two prospective studies.

Two different Clinical Appraisal Skill Program [CASP] tools (Clisby and Charnock, 2000) were used to assess the quality of the studies: CASP for RCT was used to appraise studies by Guisasola-Rabes et al. (2019), Hogan and Harvey (2015), Jousselme et al. (2011), Plummer et al. (2019), Wang et al. (2014), Engelmann et al. (2014), and Chang et al. (2006). Their scores were: 18, 17, 17, 17, 18, 19, and 18, respectively, out of a possible score of 22. In addition, CASP for the cohort was used to assess Guerra et al. (2018) and Walker and Karl (2019), and their scores were 20 and 20, respectively, out of a possible score of 24. These scores mean that the higher the score, the better the quality of the studies.

Data Extraction

Data extraction, as shown in Table 1, is the summary of the selected studies and provides details of the aims, the method and design and the key findings from the selected studies. The authors of this review extracted the data and critically appraised the selected studies independently. Any disagreement arising from the study selection and the data extraction process was resolved by consensus. The common study aim of all studies was experimenting with DND interventions to reduce noise and behavioural modification.

Table 1: Study Summary

Author (year), country	Aim and design	Method/Design	DND used, Noise Limit Setting and Recorder Location	Noise Reduction Achieved	Changing in Behaviour/ Awareness	Limitation
Chang et al. (2006) Taiwan	To evaluate the noise distribution and sudden peak noise using a noise-sensor light alarm.	**Method: Pre-test and post-test Design:** - Noise levels in incubators and radiant-heated beds, combined with ventilators, were monitored continuously for seven days. - Pre- and post-intervention of noise-sensor light alarms.	**DND:** Noise sensor light alarm **Noise limits:** - Red >65 dB(A) **Recorder location:** - Placed in incubator 10 cm away from infant's ear	- 2 dB(A) - Peak noise reduces from 630 to 185	- Not reported	- Single centre study - No subjective data
Engelmann et al. (2014) Germany	To assess the impact of a noise-reduction program	**Method: Prospective 2-armed clinical trial Design:** - Phase 1: measured noise level disguised as CO_2 meters. - Phase 2 (control group): noise level recording - Phase 3 (intervention group): the display of noise ear noise warner.	**DND:** SoundEar I **Noise limits:** - Green >60 dB(A) - Amber between 60-65 dB(A) - Red >65 dB(A) **Recorder location:** - 5 cm on the wall in the centre of the unit	- Noise levels in theatres exceeded 55 dB(A). - Background noise was approximately 20dB(A)	- The environmental noise can effectively be reduced with acceptable staff compliance by technical and behavioural measures.	- Single centre study - No subjective data
Guerra et al. (2018)	To determine the relationship	**Method: Prospective cohort study**	**DND:** SoundEar Pro **Noise limits:**	- 2.5 dB(A)	- Not reported	- Single centre study

Canada	between noise levels and patient's sedation requirements.	**Design:** - Noise level recorded over a month with SoundEar Pro - Noise recorded between 7 AM to 7 PM for daytime, and 7 PM to 7 AM for night-time	- No noise limit set **Recorder location:** - 60 cm from patients' head and bedside			- No subjective data
Guisasola-Rabes et al (2019) Spain	To estimate the effect of a visual noise-warning system on noise levels	**Method: Pre-test and post-test Design:** - Phase 1 (two weeks): baseline noise levels measure - Phase 2 (two weeks): visual noise alarm system was implemented. - Phase 3 (two weeks): system was turned off.	**DND:** SoundEar II **Noise limits:** - Green >55 dB(A) - Amber between 55-60 dB(A) - Red >60 dB(A) **Recorder location:** - In the centre of the unit, 555 cm from the ceiling and 110 cm from the wall	- No data given	- The noise reduction was maintained after the system was turned off, which suggest that the staff adopted behavioural changes that were maintained even when SoundEar II was not activated.	- Single centre study - No subjective data
Hogan and Harvey (2015) Not given	To reduce noise levels in the OR in response to complaints from the anaesthesia staff members.	**Method: Pre-test and post-test Design:** - Pre-and post-noise level measurement (1 month). - Avoid unnecessary conversation, avoid telephone conversation, lower voices, not play music, not enter the room unless needed. - Prepare all equipment in advance. Avoid opening and closing the drawer.	**DND:** Noise Level Alert Monitor **Noise limits:** - Red >75 dB(A) **Recorder location:** - The sound meter was concealed and placed 120 cm away at the levels of the patients' head.	- Post education data reflect an overall decrease in noise events beyond 70dB(A) with 63.7% during anaesthesia induction and emergence phases. -	- After educating staff members and implementing strategies to reduce noise, there was a significant improvement in noise on several different levels and a significant reduction in environmental noise levels and maximum noise levels after education.	- Single centre study - No subjective data
Jousselme et al (2011) France	To determine whether a sound-activated light alarm device could reduce the noise.	**Method: Pre-test and post-test Design:** - No present device situation - Device 'off' situation (device present and turned off) - The device 'on' situation (device present and turned on)	**DND:** Noise Sensor Light Alarm **Noise limits:** - Red >70 dB(A) **Recorder location:** - Placed microphone at the nurses' stations	- 2 dB(A)	- Noise levels decreased when the device was present regardless of whether it was turned on or off. Thus, the flashes did not seem to decrease noise directly.	- Single centre study - No subjective data

Plummer et al. (2019) UK	To determine whether a sound-activated visual display meter could cause a sustained reduction in noise levels.	**Method: Pre-test and post-test Design:** - Noise recorded over eight consecutive days without activation of a visual warning on the device. - Introduction of soundear visual warning system and noise recording over eight consecutive nights	**DND:** SoundEar III **Noise limits:** - Green >55 dB(A) - Amber between 55-60 dB(A) - Red >60 dB(A) **Recorder location:** - Placed over the centre of the nurses' stations	- 3.6 dB(A)	- It is plausible that the more significant reduction in environmental noise levels was due to direct visual feedback.	- Single centre study - No subjective data
Walker and Karl (2019) USA	Using determined existing noise reduction strategies improves patients' overall satisfaction level during hospitalisation.	**Method: Pre-and post-noise reduction intervention Design:** - No baseline noise measurement. - Staff education via poster presentation, discussion of noise reduction strategies for implementations, limiting overhead pages, remind staff for noise reduction, posting quiet signs. - Staff noise perception using an online survey	**DND:** Yacker Tracker Visual Reminder **Noise limits:** - No noise limit setting **Recorder location:** - No noise recoding	- No data given	- The use of visual cues and staff education are effective - Decreased noise levels improved overall patient satisfaction with their hospital experience.	- Single centre study - No subjective data
Wang et al. (2014) Canada	To determine if sound-activated noise meters providing direct audit and visual feedback can reduce noise levels.	**Method: Pre-test and post-test Design:** - One noise meter was placed in each patient's area (pod) and a fourth in the centre desk area. Data were collected for two months, with a threshold red 55dB(A). Data were compared between pre-intervention and post-intervention. - Two months with noise meters providing visual feedback	**DND:** SoundEar I **Noise limits:** - Green >50 dB(A) - Amber between 50-55 dB(A) - Red >55 dB(A) **Recorder location:** - One noise meter was placed in each patients' pod	- There was a statistically significant increase in the proportion of adjusted mean noise measurement <50 dB(A).	- Overall, there was no significant change in mean noise levels with direct audit and visual feedback using noise meter (due to un-modifiable factors, e.g., HVAC systems.	- Single centre study - No subjective data

Results – Data Analysis

This review used thematic analysis to synthesise the study findings. Similar themes extracted from each study were grouped to form new themes (Aveyard et al., 2016). As a result, two new themes emerged: First, “DND reduces hospital noise levels”, and second “DND raises staff’s awareness of noise levels”.

1. DND Reduces Hospital Noise Levels

All studies included in this review record and measure two different noises: environmental noise and peak noise. The difference between the two is that the former is the background noise that occurs over a given time, whereas the latter is the noise levels that peak within a specific time (WHO, 2009). By recording both noises pre-intervention and compare to noise recording post-intervention, the researchers work out how effective the DND is in reducing noise.

Five studies included in this review reported the effectiveness of DND intervention in reducing the ward’s noise levels. For example, Chang et al. (2006) evaluated noise distribution and the frequency of sudden peak noise in a Neonatal-ICU. A purposefully built DND was installed, and two microphones were placed within the incubators and the radiant-heated bed. The noise levels were monitored continuously for seven days. The researchers compared noise measurements and concluded that noise-sensor DND reduced environmental noise by 2dB(A) in incubators. In addition, there was a reduction of peak noise frequency to 70 in radiant-heated beds. However, this was a single-centre study, limiting the generalizability to other settings (Ajetunmobi, 2002).

A similar reduction was also reported by Hogan and Harvey (2015). The researchers carried out a quality improvement to reduce noise levels in the operating rooms of two community hospitals. Noise levels were recorded pre-intervention for one month. Furthermore, education on behavioural changes to participants was also given to avoid unnecessary conversation and telephone conversation, lower voices, not enter the room unnecessarily, and be mindful of patients. The researchers then recorded noise levels post-education. The study reported a reduction of 63.7% of noise peaks above 70dB(A). However, the reduction achieved was due to a combination of DND intervention with behavioural changes education. The problem is that the combination of interventions can not differentiate the result of each intervention. In addition, there was no subjective data from the participants to confirm that the noise reduction was due to the participants' behavioural change.

Noise reduction is also a key finding in Plummer et al. (2019). The researchers carried out a pilot study to determine whether the DND could sustain night-time noise reduction in an Adult-ICU. The researchers placed a noise recording microphone on the central nurses' station. At the same time, the DND was placed visibly in all bed spaces. Baseline data were recorded over eight consecutive days. The follow-up data collection took place after four months of the continuous use of the DND. The study found a significant reduction in the unit's noise levels but no reduction in peak noise levels. They also found that non-modifiable noises, such as medical devices, monitor alarms, doors, bins, and moving equipment, contribute to the spiking of peak noise levels.

Similarly, Walker and Karl (2019) carried out a study to determine existing noise reduction strategies to improve overall patients satisfaction. The researchers carried out multiple sleep-promoting interventions, including using poster presentations to staff, closing doors to patients rooms, limiting pagers, posting quiet signs throughout the unit and using the DND reminders. Staff and patients follow-up surveys reported that these interventions were effective for noise reduction. However, the limitation was that there was no objective noise level recording to back up the noise reduction report.

Similar to Plummer et al. (2019) findings, Wang et al. (2014) carried out a noise audit to determine if DND can reduce noise levels in three Neonatal-ICU. The researchers placed a DND device in each of the three patients' areas, and the fourth device was placed in the centre desk. The baseline noise level of the unit was recorded for two months and then followed by the intervention of DND for two months. The noise levels were analysed. The study found that there was no significant change in environmental noise levels. However, the noise produced by the less modifiable factors such as ventilators and air conditioning continuously caused considerable background noise. The limitation to this study is that there was no feedback from staff or patients regarding the effectiveness of the noise reduction program.

Equally, Engelmann et al. (2014) reported that the non-modifiable factor raises environmental noise levels. The researchers carried out a prospective 2-arm clinical trial to assess the impact of the noise-reduction program in a paediatric operating theatre. They measured noise level in phase-1 with slow-motion sound probes disguised as a CO_2 meter. In phase-2 (control group), they performed sound pressure recordings. During the intervention, a conference was held to disclose the study purpose and introduction of work rules. In phase-3 (intervention group), DND was attached to the four theatres walls at eye level. They reported no significant changes in environmental noise levels and peak noise. This is due to the noise caused by non-modifiable factors such as air-conditioning, warming blankets, or alarms which was approximately 20dB(A). However, the research design lacks subjective data on the participants' experiences on the effectiveness of the DND intervention. The questionnaire completed by the surgeons at the end of the operation was focused on behavioural stress responses to unwanted noise and post-operative complications instead of assessing the effects of DND intervention on noise reduction.

Furthermore, Guerra et al. (2018) carried out a prospective observational study to determine the relationship between noise levels and patients' sedation, comparing day (7 AM-7 PM) and night-time (7 PM-7 AM) in a Pediatric Cardiac ICU. Noise levels were recorded for four weeks. The researchers also recorded intermittent sedation drug doses to explore the association between drug use and noise levels. They concluded that the average noise level in the open area was 59.4 dB(A), with a statistically significant difference 2.5 dB(A) between day and night [night being lower than days]. There was no significant reduction between open area and single room for both day and night.

2. DND Raises Staff's Awareness Towards Noise Levels.

Five studies concluded that noise reduction was achieved due to changes in staff behaviours and awareness when exposed to the DND intervention. For instance, Guisasola-Rabes et al. (2019) carried out a quality improvement intervention to estimate the effect of a DND on noise levels in a Surgical-ICU. In phase-I of their study, the researchers recorded noise levels for two weeks, followed by two weeks of DND system implementation. In phase-II, two units of SoundEar II was installed in the Surgical-ICU. In Phase-III [for two weeks], the DND was turned off. The study result showed that the noise reduction was maintained even after the system was turned off for four months. The researchers claimed that the DND intervention had positive effects on the staff's behaviour. However, in a similar way as Engelmann et al. (2014), the research design did not include subjective data from staff and patients to validate the claim. Furthermore, a single-centred study may limit the generalizability to other settings (Ajetunmobi, 2002).

Plummer et al. (2019) also concluded that direct visual feedback of DND intervention could modify staff behaviour and raise their awareness. Similarly, Hogan & Harvey (2015) and Walker & Karl (2019) also concluded that noise reduction was due to the increment in staff's awareness and quieter preparation of surgical instrumentation.

In contrast, Jousselme et al. (2011) concluded that the presence of DND did not influence staff behaviour. The researchers carried out a quasi-experimental to determine whether DND could reduce noise in a Paediatric-ICU without the involvement of human participants. The noise was recorded with a sonometer while the DND device was displayed. They recorded noise levels without the presence of DND. They then re-recorded noise levels with the DND present but turned off. The researchers re-recorded the noise with the DND present and turned on. After three months, the researchers re-recorded noise without the presence of DND. The researchers concluded that DND reduced the PICU noise levels by 2dB(A). The findings are interesting because noise levels decreased when DND was present regardless of whether it was turned on or turned off, which means the flashes [display] did not decrease noise levels directly. It also suggests that the presence of the device could lower staff-produced noise levels. However, the lack of subjective data from staff to validate the result was the limitation of the study. The noise reduction achieved could have been influenced by the hawthorn effect due to the visible recording device and the researcher's presence on the unit (Ajetunmobi, 2002).

Discussion

This review found that the levels of noise reduction achieved through the DND intervention are varied between the studies included in this review. Two fundamental factors influencing the variation are the noise limit setting and the noise recorder's location. The former relates to the noise levels set by the researchers to trigger changing of colours on the DND equipment. As shown in Table 1, each study sets its noise limits for the DND equipment that were not uniform. Four studies (Engelman et al., 2014; Guiasola-Rabes et al., 2019; Plummer et al., 2019; Wang et al., 2014) sets their DND noise limit for each colour, whereas three studies (Hogan and Havey 2015; Jousselme et al., 2011; Chang et a., 2006) only set for upper [red] limits. Two studies (Guerra et al., 2018; Walker and Karl, 2019) did not set noise limits. The latter is related to the noise recorder location placed by the researcher on the ward or unit. The location of the noise recorder in each study was also different. This is important because the distance of the recorder from the noise source can potentially affect the noise level reading (Srinivasa et al., 2017).

The selected studies have achieved noise level reduction ranging between 2dB(A) to 3.6dB(A). Although the level achieved was small, it was significant to noise perception in the human ear. A 3dB(A) reduction is equal to an approximately 50% reduction of environmental noisiness (WHO, 2009).

In most studies, noise reduction was achieved due to staff and patient behaviour changes. Staff and patients became more aware of the noise levels. To some extent, this claim is valid as there is evidence of noise reduction reported in each study. However, all studies have common minor limitations. All studies lacked subjective data from staff and patients, which are crucial in understanding the effect of the DND intervention on the participants' behaviour and awareness. It is the key to understanding the feelings, challenges, implications, reasons, and decisions that may influence behavioural change (Foreman et al., 2015). Through subjective data, one can explain whether the DND intervention influenced the behavioural change because adjustments in behaviour in the selected studies may not be due to the implementation of the DND. For example, Jousselme et al. (2011) concluded that the environmental noise levels decreased by the presence of DND regardless of whether it was turned on or turned off. That suggests the DND flashes did not influence the staff's behaviour and patients directly.

The strength of this review is that it systematically uses PRISMA guidelines to select the most relevant studies for review by setting the protocol using the PICO method and performing a critical appraisal using CASP validated tools. The method of deductive selection initially screened the title abstract, followed by process of in-depth screening to locate the most relevant articles (Aveyard et al., 2016). However, as in any well-designed study, there are always notable limitations, and that this review is no exception. First, the inclusion criteria were limited to only studies published in the English language. This inclusion may potentially exclude good quality of study that published in other languages. Second, the limitation of the study to ten years may limit some excellent and relevant studies, as demonstrated by Chang et al. (2006), which was identified from tracking references within the selected studies.

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Conclusion

The introduction of DND for noise reduction in hospital settings to improve patients' sleep is achievable. All studies included in this review have provided evidence that DND intervention can reduce the noise between 2dB(A) – 3.6dB(A). However, the claim that DND raises staff awareness is only hypothetical at this point. There is a lack of evidence to support the claim. A further study exploring the participants' experiences when exposed to DND intervention is necessary to understand how the intervention influences behaviour changes or raises awareness.

CPD Reflection Questions

- What are the challenges of increased noise levels to staff and the patients in your area?
- Reflect on your area, identify three sources of noise that can disturb your work and your patients' sleep!
- What is noise reduction intervention available in your area?
- In your opinion, what are the challenges to the intervention of DND in your area?

KEY POINTS

- Hospital environment noise is now increasingly recognised as a global healthcare challenge.
- Hospital wards or units identified the need for exploring the effectiveness of DND in noise reduction intervention to improve patients' sleep quality.
- DND has a potential effect on staff behaviour to conform to noise reduction intervention

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