The Effect of Noise-reducing Acoustic Panels on the Noise Levels and Overall Safety of Infant Sleep Machines

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Infant sleep machines (ISMs) are devices used to help infants fall asleep faster and stay asleep for longer amounts of time, yet they can often be too loud for infantile ears, which could potentially be dangerous. This research aimed to minimize the risks of infant sleep machines without reducing the effectiveness of the infant sleep machines themselves through the use of acoustic panels. Based on previous studies, it was hypothesized that the acoustic panels would reduce the noise levels of the ISM to less than recommended limits of 50 dB-A. A specific corner of a designated room was prepared with a crib with a sound level meter placed inside and a table housing the ISM all to simulate a sleeping infant being exposed to the white noise from the ISM. After 30 trials were conducted without any soundproofing, another 30 trials were conducted after acoustic panels were placed on the walls behind the crib in order to reduce the noise levels of the ISM. Significant differences were found between the two groups, with the t-statistic of 30.9688 being much higher than the critical value of 1.697, and the p-value being less than 0.001, all with an alpha of 0.05. Finally, it was found that acoustic panels did reduce the noise levels to below less than 50 dB-A, which means the hypothesis was supported. This shows that acoustic panels have a significant effect on noise reduction for infants and are a safe, inexpensive option for parents.

Introduction

In today's world, there are so many parenting blogs, websites, and general tips that are circulating online for new parents to learn about how to take care of their children. One of the most prevalent issues that parents face is putting (and keeping) their children to sleep. A variety of parenting blogs suggest white noise machines, also known as infant sleep machines (ISM), to help relax their children for a good night's sleep.

White noise is noise that contains many different frequencies at the same intensities, and it provides a good masking effect for reducing environmental noises that keep people awake during the night. According to some parenting blogs, white noise can simulate "a womb-like environment that is comfortable and calming" for the infant (Coleman, 2020). Also, ISMs have been marketed based around two factors, which are "to provide ambient noise to soothe an infant during sleep or to mask disturbing environmental sounds by producing louder sounds and there-fore preventing arousal from sleep" (Hugh et al., 2014).

However, studies have shown that many of these machines can produce sound levels far exceeding safety limits for many infant users. Specifically, a study published in the journal *Pediatrics* by a team of researchers from the Department of Otolaryngology at the University of Toronto found that 14 widely recommended ISMs that they studied all exceeded hospital recommended limits of 50 A-weighted dB from multiple distances after an hour of usage by up to 85 db-A (Hugh et al., 2014). These levels of noise could cause lasting damage, including noise induced hearing loss, physiological and psychological changes, and impaired cognition (Corra, 2004; Gray & Philbin, 2000). Because no solution outside of hearing aids has been found to remedy noise induced hearing loss, Harrison, a researcher from the Department of Otolaryngology at the University of Toronto, suggests focusing on preventative methods rather than curative ones (2008). However, nothing of the sort has been addressed other than general safety guidelines. Some findings question the utility of the white noise machines in the first place, implying that it may be better to not use them because of these harmful effects.

Patrick A. Coleman, a writer at the parenting blog *Fatherly*, gives a list of tips that may offer some protection against the safety concerns. Included in the suggestions, he urges the reader to, "choose white noise baby machines that are low pitched but produce steady sounds," and to "turn white noise machines all the way down" (Coleman, 2020). This shows how important it is to inform parents of any general tips that could be used to reduce harmful noise outputs. He even acknowledges in a later statement that "most machines can exceed the maximum decibel level recommended for hospital nurseries" (Coleman, 2020), like Hugh et al. studied. Evidently, the study by Hugh et al. also recommends similar guidelines to avoiding safety hazards. Hugh et al. backs Coleman's claims that playing the ISM at a low volume will may lead to an overall safer usage. However, they also suggest that playing the ISM from a farther distance and for a shorter duration of time may mitigate any safety concerns as well (Hugh et al., 2014). Hugh et al. also have some policy recommendations for manufacturers of the machine, including requiring them to limit maximum sound output levels for the ISM, requiring them to print warnings about noise induced hearing loss on the machines, and requiring them to insert mandatory timers into the machines to avoid overexposure (2014). These sources highlight how safety methods should be accessible because, as parents may not have a lot of time or money to set up advanced noise reduction programs such as products used in hospitals, for example.

Other studies have delved into how methods for sleep aid may work with other types of people. A study by Lucy Handscomb, a researcher at the audiology department of St. Mary's Hospital in London, tested a similar device for tinnitus patients, bedside sound generators with different noises similar to white noise machines (2006). The tinnitus patients that were part of the experiment were mostly found to use water noises, and least often used white noise, which was surprising considering how recommended white noise is in similar situations such as tinnitus therapy programs. However, other researchers have doubted the efficacy of the white noise machines to begin with, and wonder if they should be used at all as the risks may outweigh the benefits. For example, a group of researchers at the Unit for Experimental Psychiatry, Division of Sleep and Chronobiology, University of Pennsylvania Perelman School of Medicine reviewed 38 different studies that experimented with continuous white noise as a sleep aid. They used the GRADE criteria in order to review each article and assess whether the evidence given by the study was effective in proving that white noise is a successful sleep aid or not. They concluded that the quality of evidence throughout the sources that supported the aforementioned statement was very low, which correlates with Handscomb's findings.

Yet some methods don't involve the introduction of more noise that could potentially be harmful. German researchers who specialize in sleep medicine and otorhinolaryngology (which concerns diseases of the ear, nose, and throat) studied how a room's acoustics could affect sleep quality (Fietze et al., 2016). They recorded polysomnography (consisting of brain waves, oxygen levels in the blood, heart rate and breathing, as well as eye and leg movements), nocturnal noise levels, and a subjective sleep quality measurement of 24 healthy sleepers in both a normal room and an acoustically isolated room. After experimentation, they found that the acoustically isolated room increased deep sleep and REM latency, decreased the number of arousals during sleep, and observed an general increase in sleep quality. According to Riedy et al., similar improvements were also noticed during experimentation with white noise (2021). Finally, Fietze et al. discussed how poor sleepers and insomniacs should look into reducing noise levels and reverberation into aiding their sleep (2016).

This is ultimately where the gap in this research lies, between using acoustical methods and white noise as sleep aids. As for keeping with the recurring topic of accessibility for parents, white noise machines are easily found in many different stores, while acoustic panels can also be easily obtained and set up. Using both of them in conjunction may provide a method of solving each's detriments. Specifically, if acoustic panels are used to reduce the noise levels coming from infant sleep machines, then the sound would be reduced to below current hospital recommendations of >50 dB-A because the shape and materials of the panels are designed to reduce environmental noises, including white noise.

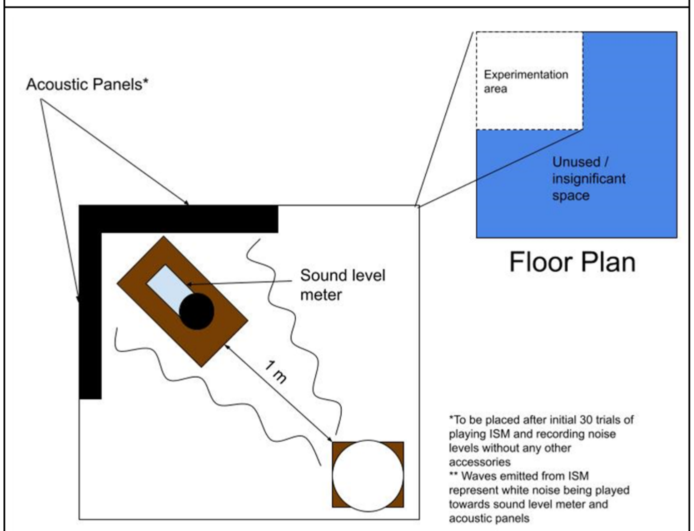
Methods

The research addressed the literature gap that acoustical engineering could play a role in reducing harmful noise in these sleep environments. Infants can face many sleep problems, such as night wakings, which can be harmful to the infant's health, even as they age. White noise is definitely one method of mitigating these issues, but recent developments have shown some of its harmful effects. A study found that "ISMs are capable of producing output sound pressure levels that may be damaging to infant hearing and auditory development" (Hugh et al., 2014). Through the use of acoustic panels, which are already a commonly used item among the public for sound absorption purposes, the harmful outputs that ISMs produce may be able to be mitigated. Also, both ISMs and acoustic panels are frequently used among society, so use of both of these accessible objects will promote healthy sleep in infants with minimal repercussions.

In this research, a complete nursery for a sleeping infant cannot be replicated, which is why a smaller-scale simulation was chosen for experimentation. The complete nursery is not feasible due to time, space, and financial constraints. This is why a smaller-scale simulation was chosen, to replicate the general benefits and restrictions of a nursery and to test if the new addition of acoustic panels are actually viable and useful in a larger-scale, more applicable environment.

Before experimentation, a designated room was prepared for experimentation. To do so, a specific corner of the room was cleared out so that materials could be placed. The setting replicated a natural home environment that infants would most likely be sleeping in, which Cautilli used in his own study (2005). The placement of all materials was completed beforehand to see if any object did not fit in the designated area. A sound level meter recording sound levels through the A-weighted dB scale was used for measurement, as Gray & Philbin recommend doing so in their own article discussing how to measure sound levels in hospital nurseries (2000). Two tables were used, one on which a file crate housing the sound level meter would be placed right near the corner. The file crate was used to represent a crib that the infant would be sleeping in. The other table was placed exactly 100 cm, or 1 m, away diagonally from the sound level meter for the white noise machine to be put on. Hugh et al., which was a previous study that tested distances of 30cm, 100cm, and 200cm, was used as a basis for this 100cm distance, as they felt it would be the most balanced option of the three. (2014).

Figure 1. A Diagram of the Room Setup, which is a representation of the complete setup for experimentation. The sound level meter was placed on a table near a corner of the designated room. The infant sleep machine (ISM) was placed on another table 1m diagonally away from the sound level meter. Acoustic panels were placed along the corner walls.



Once experimentation started, the sound level meter and the white noise machine were placed in their respective locations. The ISM was placed to face the sound level meter and the corner. A specific volume setting was marked on the machine, and then the volume dial was turned to that spot for a set volume. The ISM would then play for a total of 30 seconds. Around the time that the stopwatch displaying time hit 30 seconds, the noise levels measured by the sound level meter were recorded on the data table. This was repeated for a total of 30 trials. Hugh et al. also chose to conduct 30-second trials for each group they had in their study, which was why this study chose to use 30-second trials.

After these 30 trials were completed, the acoustic panels were mounted along the walls of the corner with mounting squares, surrounding the sound level meter on two sides. This was to ensure that the sound absorption coefficient would be higher, thus reducing the amount of noise that would surround the "infant" (Amares et al., 2017). The panels themselves were all placed adjacent to each other, and they were all completely surrounding the sound level meter on its backside, unlike other situations where some may space the panels out. 30 trials were then conducted and recorded again, with the same procedures and units of the first 30 trials, but with the new addition of the acoustic panels.

Figure 2. Experimental Design Diagram

Hypothesis

If acoustic panels are used to reduce the noise levels coming from infant sleep machines, then the sound will be reduced to below current hospital recommendations of >50 dB-A because the shape and materials of the panels are designed to reduce environmental noises, including white noise.

Independent Variable

The use of acoustic panels to reduce noise levels coming from ISMs

Levels of Independent Variable	No acoustic panels used (control)	All 12 Acoustic panels
Number of Repeated Trials	30	30

Dependent Variable

The noise levels (dB-A) recorded by the sound level meter

Control Group

When acoustic panels were not used, and the sound level meter recorded the noise levels of the ISM with no other accessories

Constants

Same equipment used for all experimentation
Location of sound level meter, ISM, and acoustic panels
Sound levels in the immediate environment
Volume of the ISM
Location of any other objects in the unused space that may affect acoustical properties

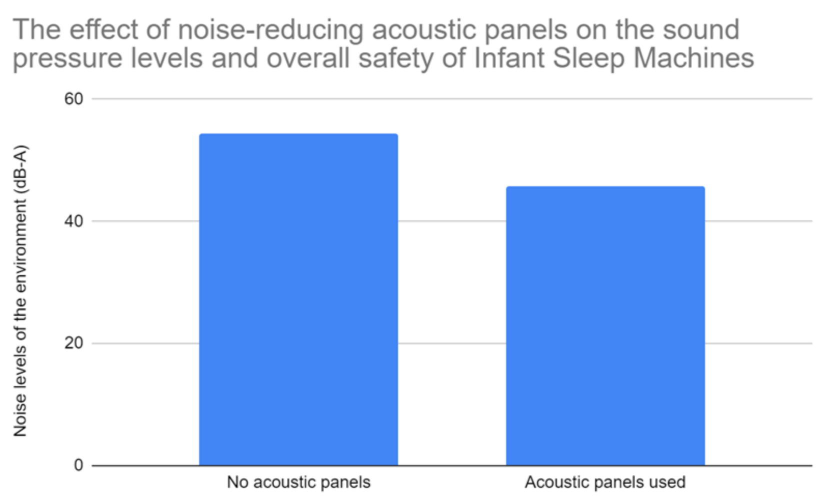
Results

The results consisted of one data set outlining the noise levels with and without the use of acoustic panels. First, the noise levels measured in the environment were recorded in A-weighted decibels. The normal environment had average noise levels of around 54.37 db-A. It also had a standard deviation of 1.23 dB-A. After acoustic panels were added, the average noise levels recorded while the ISM was playing was around 45.83 dB-A. This group's standard deviation was 0.87 dB-A. All of this is displayed in Table 1 below, and it is also graphically represented in Figure 3 as well.

Table 1. A summary statistics table of engine run times, showing how different the noise levels were when not using acoustic panels versus using acoustic panels. A key trend that can be seen is that using acoustic panels did have lower average noise levels than when acoustic panels were not used.

	Average Noise Levels (dB-A)	**Standard Deviation (dB-A)**
No acoustic panels used	54.37	1.227
Acoustic panels used	45.83	0.8738

Figure 3. Bar Graph displaying a graphical representation of summary statistics

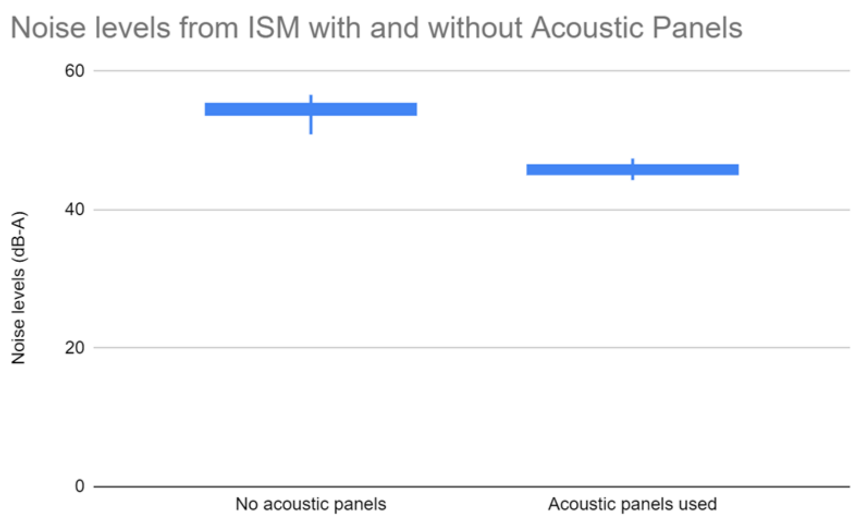


An unpaired t-test was conducted to test the significance of the data, and the test showed that there were very significant differences between the treatments, with the t-statistic of 30.97 being much greater than the critical value of 1.697 at an alpha of 0.05. The p-value was <0.0001, which indicates statistical significance. With this, the null hypothesis was rejected, indicating significant differences in the mean noise levels between the two groups. These results can be found in Table 2.

Table 2. A t-test of noise levels with and without use of acoustic panels, which shows a significant difference between noise levels for the two treatment groups, with the T-statistic of 30.9688 being much greater than the critical value of 1.697.

	No Acoustic Panels used	Acoustic Panels used
Sample Size	30	30
Sample Mean	54.37	1.227
Sample Standard Deviation	45.83	0.8738
Pooled Standard Deviation	1.065	
Standard Error of Difference	0.275	
T-statistic	30.97	
p-value < 0.0001		

Figure 4. The box plots of noise levels, displaying the variance of each treatment group in terms of noise levels. Both treatment groups had similar spreads, yet the group where acoustic panels were used does seem to have a slightly lower spread than the group without acoustic panels.



Discussion

The purpose of this study was to test if acoustic panels make a significant difference in mitigating noise-induced hearing loss in infants that may be associated with harmful usage of white noise machines. Noise induced hearing loss is very dangerous and can be common under harmful conditions, so ways of mitigating harmful factors is a priority (Harrison, 2008). Acoustic panels were chosen to help with this due to their widespread use and accessibility to the general public for noise reduction purposes.

It was determined that acoustic panels reduced the noise levels coming from the ISM to under recommended guidelines of <50 dB-A. A t-test conducted on the noise levels revealed that the T-statistic was much higher than the critical value of 1.697 at an alpha of 0.05, showing that there is also a significant difference between the two groups in terms of noise levels. Acoustic panels, which have been used anywhere from inside homes, to recording studios and concert halls, have been designed to reduce noise levels and isolate sound, which is most likely why they were effective within this experiment too. Acoustic panels have a relatively good SAC (sound absorption coefficient), which also helps explain the results (Amares et al., 2017)

Without acoustic panels, the noise levels of the ISM exceeded the recommended limits by almost 5 decibels on average. On top of that, the ISM was playing at a lower volume setting and at a farther distance, which indicates that it could be very harmful in many situations for infants. This lines up with the initial study by Hugh et al., who also experimented with ISMs under different conditions and found that they had the potential to be very hazardous in terms of noise levels for infants and children (2014).

In conclusion, the hypothesis was supported. The acoustic panels were effective in reducing the noise levels to be safer for infants and children to listen to. The differences between using acoustic panels and not using acoustic panels was also shown to be statistically significant. The p-value from an unpaired t-test that was conducted after experimentation was shown to be less than 0.0001, indicating extreme statistical significance. This shows that the acoustic panels had a significant effect on the noise levels, and that they have applicable uses for similar situations.

Although the data given was tested and confirmed to be normally distributed, certain procedural factors could have skewed the data. For example, rather than taking the measurement of noise levels coming from the ISM at the end of each trial as it was done, if the average noise levels throughout the playing time of the ISM was calculated, a more accurate portrayal may have been given.

However, one concern is that if the recommended limits of <50 dB-A actually hold up, or are purely theoretical. This would call for continued experimentation and research within this study as well, as the average noise level with acoustic panels used were 45 dB-A, which is not that much lower than 50 dB-A. 45 dB-A still could be harmful to infants, which would need to be experimented under safe conditions with actual infants.

As such, future studies could aim to experiment with these procedures on actual infants, in order to find if the ISMs remain as effective at fostering better sleep at lower noise levels. Actual clinical trials would further increase the body of knowledge surrounding the safety and efficacy of these ISMs in conjunction with the acoustic panels. Another future study could be to use different methods of noise reduction, such as an incubator-based active noise control device studied by Hutchinson, Du, & Ahmad inside the loud environment of a neonatal intensive care unit in a hospital (2020).

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Appendix

Table 3. Raw Experimental Data showing exact data within each trial throughout the experimentation process

	Noise levels of the environment (dB-A)	
Trial	No acoustic panels	Acoustic Panels used
1	56.6	46.2
2	53.3	45.5
3	53.8	44.4
4	52.4	45.7
5	53.4	45
6	53.8	45.2
7	54.8	46.3
8	50.9	45.2
9	53	46.1
10	54.2	45.5
11	55.3	46
12	53.9	44.7
13	53.8	45.4
14	54	44.7
15	53.4	47.1
16	53.9	44.8
17	53.7	45.7
18	55.3	45.5
19	54.4	46.9
20	53.9	47.1
21	54.3	44.3
22	54.3	45.9
23	55	46.4
24	54.5	45.6
25	55.3	47.2
26	55.1	45.3
27	55.6	46.1
28	56.4	46.6
29	55.5	47.1
30	56.6	47.4