Characterizing the ambient sound environment for infants in intensive care wards

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Key words: Newborn Intensive care Unit (NICU), Paediatric Intensive Care Unit (PICU), sound, noise, auditory stimulation

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What is already known on this topic

Noise is customarily discussed as a singular phenomenon to be avoided in hospitals.

The recommended ambient sound levels for hospitals are difficult to meet.

New hospital construction provides a quieter sound levels.

What this paper adds

Noise is can be usefully characterized as ongoing ambient sound (OAS) and noise events.

Ventilatory equipment in Neonatal and Pediatric Intensive Care Units may produce higher OAS than the Special Care Nursery (SCN), but the quieter OAS in the SCN makes it susceptible to higher rates of noise events.

ABSTRACT

Aim

To characterize ambient sound levels of paediatric and neonatal intensive care units in an old and new hospital according to current standards.

Methods

The sound environment was surveyed for 24 hour data collection periods ($n=80$) in the Neonatal and Paediatric Intensive Care Units (NICU and PICU) and Special Care Nursery (SCN) of the old and new Royal Children's Hospital Melbourne.

The ambient sound environment was characterized as the proportion of time the ongoing ambient sound (OAS) met standard benchmarks, the mean 5-sec sound levels and the number and duration of noise events.

Results

In the old hospital none of the data collection periods in the NICU and PICU met the standard benchmark for ongoing ambient sound, while only 5 of the 22 data collection periods in the new hospital met the recommended level. There was no change in proportion of time at recommended L_{eq} between the old and the new SCN. There was strong evidence for a difference in the mean number of events $>65\text{dBA}$ (L_{max}) in the old and new hospital (rate ratio = 0.82, 95% CI: 0.73 to 0.92, $p=0.001$). The NICU and PICU were above 50dBA in 75% of all data collection periods, with ventilatory equipment associated with higher ongoing ambient sound levels.

Conclusions

The OAS suggests that the background sound environment of the new hospital is not different to the old hospital. However, there may be a reduction in the number of noise events.

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Introduction

The ambient sound environment of intensive care settings may alter the sleep states of infants and children^{1,2} and may modulate long-term neurodevelopmental outcome³. In paediatric healthcare, medically complex newborn infants are cared for in diverse settings including Neonatal Intensive Care Units (NICU), Special Care Nurseries (SCN) and Paediatric Intensive Care Units (PICU). These settings are culturally specific with variation in the physical space, service delivery, and provisions for care and family's experience. To date, the only published study of ICU auditory environments in Australian healthcare has been for a general adult intensive care unit⁴.

Current recommendations for ambient sound

The current Australian standard for sound levels in NICUs and SCNs is a logarithmic average (known as the L_{eq} which is the equivalent to the hourly average sound level) of 40-45dBA or less at all times⁵, while the broader standards for Australian hospitals also recommend a minimum sound level (L_{min}) of <40dBA⁶. The American Academy of Pediatrics Committee on Environmental Health⁷ and the Consensus Committee for NICU Design⁸ further recommended that the hourly maximum sound level (L_{max}) should be <65 dBA, and no more than 10% of each hour (L_{10}) should be >50 dBA. These additional limits are intended to promote speech intelligibility at a normal level of effort, protect speech privacy, protect sleep and minimize distraction for infants⁸.

While minimizing noise has been a focus of clinical monitoring and research for the last decade, attention is now turning to more purposeful construction of a suitable auditory environment needed for satisfactory development of the hospitalized newborn infant⁹⁻¹². While these standard sound levels broadly delineate the ongoing ambient sound (OAS) level in the unit, the presence of sudden and unpredictable noise events should also be considered for its likely role in disrupting infant state and negatively impacting quality of sleep¹³.

In 2011, The Royal Children's Hospital Melbourne moved from a 1960's building to a newly constructed hospital, providing a rare opportunity to compare traditional and modern auditory environments. The purpose of this study was to characterize both the ongoing ambient sound and noise events in three care environments for hospitalised infants.

Method

We measured the sound environment in three hospital settings where critically ill newborn infants are cared for: NICU, SCN and PICU units. The ongoing ambient sound was benchmarked against the Australian standards for L_{eq} , L_{max} and L_{min} . Noise events, defined below, were characterized as $>65\text{dBA } L_{max}$, and sound peak events. The study was approved by the Human Research Ethics Committee.

Study design and data collection

In the old hospital, the PICU contained 7 rooms with 4 – 5 beds per room, and one room with one bed. The NICU and SCN were co-located in a refurbished ward, with 5 rooms containing 4 beds, and two rooms containing 2 beds. In the new hospital, the PICU and NICU had 30 and 12 individual rooms respectively, arranged as pairs of rooms divided by a sliding glass door. The SCN had 7 two-bed rooms arranged in pairs of rooms divided by a sliding glass door. Because of the disparity in room sizes between wards and between the old and new hospital, equitable area measurements were not possible. Instead, individualized bed measurements were made at approximately the same distance from the infant in each bed position. Data were collected for a single 24 hour period to capture the variation in the auditory environment across a full day^{14,15}. All measurements were in open air (none inside incubators).

Loudness data were collected with a Class 1 Quest SoundPro DL Sound Level Meter (SLM) (Quest Technologies) set for A-weighted slow response mode (dBA Slow) as specified for the standard benchmarks. The sound level was recorded in 5-second epochs¹⁵. The microphone (Class I BK4936, Brüel & Kjær) was isolated from the SLM using a one metre extension lead connected to the microphone. A microphone stand and boom arm were used to place the recording microphone at the head-end of the patient's bed, as close to the patient's head as could safely be achieved. The SLM was calibrated at the

commencement of each data collection against a 1kHz 114dB pure tone from the manufacturer's acoustic calibrator (QC-10). Equipment in use at the time of recording was catalogued for the individual bed, and for adjacent bed spots in the area of recording¹⁶. Equipment was grouped as ventilators or infusion pumps (feed, syringe and volumetric).

Data was collected in every occupied bed in each unit in both hospitals. The SLM data was stored on removable storage cards and transferred to a central database (QuestSuite Professional II version 5.0.2317).

Analysis

The OAS was measured with the mean 5-sec L_{eq} , L_{max} and L_{min} ¹³ and the proportion of time in the 24 hour data collection period (DCP) where the L_{eq} was equal to or less than the benchmark of 45 dBA_{slow}. The change in mean L_{eq} , L_{max} and L_{min} , 95% confidence interval (CI) and p-value between hospital and unit was estimated from a linear regression model fit with log-pascals and back transformed to dBA for presentation. The difference in the proportion of time in the DCP where the L_{eq} was less than the benchmark of 45 dBA is assessed with the Kruskal-Wallis equality-of-populations rank test.

Two types of noise events were measured¹⁷. First, the >65dBA L_{max} events commenced with any recording of 65dBA or greater and ceased when the sound reduced below 65dBA

for at least 40 seconds; and second, the Sound Peak (SP) events were defined as a jump of at least 12dBA between two consecutive 5 second readings in the L_{eq} to identify detectable events for newborn infants.

For each noise event we present the median and inter quartile range (IQR) of the number of events for the old and new hospital, and for each of the units. The data were log-transformed and we used linear regression to estimate the mean percentage increase between hospitals and units, as well as the 95% CI and p-value for that increase. The duration of event is discussed descriptively only as the data were strongly skewed. Additionally, for each outcome measure we assessed the evidence for a difference between rooms with and without equipment and between day (7:00 to 22:59) and night (23:00 to 6:59) using linear regression as above. All analyses were performed in Stata 13 (StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP).

Results

Ongoing ambient sound

The OAS environment of all units in both the old and new hospitals exceeded the L_{eq} and L_{max} levels stipulated by the Consensus Committee for NICU Design (Table 1). The L_{min} levels which provided a sound “floor” for the OAS not only exceeded the benchmark for L_{min} , but also for the L_{eq} .

[Insert Table 1. OAS levels in the old and new hospital]

Table 2 shows the estimated change in the OAS environment between the old and new hospital, after accounting for unit, and between units after accounting for hospital.

[Insert Table 2. Changes in OAS environment]

In the old hospital, no DCPs in the NICU and PICU met the recommended L_{eq} , while in the new hospital the L_{eq} was only below 45 dBA in 5 of the 22 DCPs. The median proportion of time below 45dBA in those 5 cases was 6% [range 2% to 41%]. In the SCN, there was no evidence that the proportion of time at the recommended L_{eq} differed between the old and the new hospital (old: median 20% [IQR 17% to 29%]; new: median 28% [IQR 23% to 37%], $p = 0.12$).

Noise events

The number of each type of noise event is shown in Table 3.

L_{max} Noise events (over 65dBA)

There was a decrease in the mean number of L_{max} events from the old and new hospital (rate ratio = 0.82, 95% CI: 0.73 to 0.92, $p=0.001$). There was no evidence for a difference

in the number of $L_{\max}$ events between the NICU and SCN, and between NICU and PICU however there was strong evidence that PICU had more events than the SCN (rate ratio = 1.26, 95% CI: 1.10 to 1.45, $p = 0.001$) (see Table 3).

The duration of noise events across the data was strongly skewed. In 50% of the events in both hospitals and each unit the duration of events was less than 55 seconds (IQR: 40 seconds to 85 seconds, max: 41 minutes).

[Insert Table 3: Number of events between old and new hospital and between units]

Sound Peak events (12dBA jump)

In all units, the number of SP events was observed to be larger in the new hospital than in the old hospital. The new hospital was estimated to have 4.1 (95% CI: 2.8 to 5.9, $p < 0.001$) times the number of events. The number of events was observed to be greatest in the SCN, which was estimated to have 5.8 (95% CI: 3.6 to 9.5, $p < 0.001$) times the number of events as the NICU. There was no evidence for a difference in the number of events between NICU and PICU (Rate ratio 0.9, 95% CI: 0.6 to 1.3, $p = 0.5$).

Effect of equipment in room

The only equipment present in the SCN are infusion pumps. Therefore we investigated the effect of mechanical ventilation equipment only in the NICU and PICU. There was some

evidence for a difference in the OAS between rooms with and without ventilation equipment, although the magnitude was small.

[Insert Table 4 Effect of ventilation equipment on the OAS]

There was no evidence for a difference in the rate of >65dBA noise events in rooms with and without equipment, however there was moderate evidence that the rate of SP events decreased in rooms with equipment by 53% (rate ratio= 0.47 (95%CI: 0.28 to 0.79, p=0.01)

There was little change in the duration of >65dBA $L_{\max}$ events in both hospitals and both units, with at most a median difference of 5 seconds between rooms with and without equipment.

Day and night

There was no evidence for a difference in OAS between day and night in the OAS of the old and new hospital (Table 5).

[Insert Table 5 OAS levels day vs night]

There was strong evidence for a difference in the rate of >65dBA $L_{\max}$ events between day and night (rate ratio = 1.6, 95%CI: 1.4 to 1.7, p<0.001), but not in SP events. There was

little change in the duration of $>65\text{dBA } L_{\text{max}}$ events in both hospitals and both units, with at most a median difference of 5 seconds between day and night events.

Discussion

In a comparison of the old and new hospitals, there was no evidence for a significant difference in OAS. This unexpected finding tests the idea that newer building fabrics and design would change the overall sound environment, but confirms previous findings that dynamic human activity such as nursing care and medical treatment cause significant noise. Measurement of the customary markers for ongoing sound levels (L_{eq} , L_{10} and L_{max}), showed no evidence that the new hospital was quieter than the old hospital.

Overall the NICU and PICU exceeded not only the L_{eq} benchmark of 45 dBA most of the time, but also the benchmark of L_{10} 50dBA, which should be exceeded only 10% of the time.

The comparison of the OAS suggests that the sound environment of the new hospital is not different. However by considering both ongoing ambient sound and noise events, there is evidence of improvement. In both hospitals there was evidence that the number of 65dBA noise events is higher in the PICU than the SCN. However after accounting for the effect of the unit, there is still strong evidence that the new hospital has fewer noise events above the L_{max} level of 65dBA, supporting a benefit of individual rooms. This is confirmed by the

finding that in the SCN there were more SP events (a jump of 12dBA) than in the NICU and PICU. The SCN in the new hospital continues to house two beds in each room with less space between beds than in the old hospital. Noise from adjacent beds and rooms are likely to have contributed to the increased number of SP events recorded in this setting.

Analysis of the NICU and PICU rooms with and without ventilators revealed similar patterns of high ongoing ambient levels, the main effect of equipment being a 24 hour sound “floor” well above 50dBA in 87% of rooms with equipment. We did report the expected patterns with OAS reducing overnight. However the lower OAS overnight leaves the environment more vulnerable to SP noise events which are believed to disrupt infant sleep¹³.

The existing recommendations for L_{eq} , L_{10} and L_{max} have provided important benchmarks for noise in intensive care environments. However, studies across the last 10 years have shown that the levels are generally not attainable in a functioning NICU^{16,17}. The original bases for existing recommendations included the minimisation of sleep disruption and interference in speech intelligibility among adults¹⁸. The signal-to-noise ratio of the speech intelligibility assumed a distance of 12 feet (3.7 meters) between nurses in an open bay unit (i.e., nurses able to hear each other speaking at normal loudness level at a distance of 12 feet). In the single or even double bed rooms of the modern hospital the distance between

nurses is reduced by the physical dimensions of the room, or by the use of wireless handset devices between nurses. Therefore speech intelligibility may no longer be a relevant determinant in modern intensive care units. Consideration of recent studies might inform a review of both the American and Australian standards to produce more useful guidelines for the functioning intensive care environments.

Aligned with Kuhn's findings¹⁹ for very preterm infants, we postulate that repeated exposure to sudden onset and dramatic noise events (such as $L_{\max}$ and SP events) is more likely to cause disruption to sleep and should therefore be a key consideration in further research.

The traditional focus on attenuating ambient sound has recently been counter-balanced by reports of poorer neurodevelopmental outcomes for preterm infants cared for in single rooms²⁰. In practice, attention to the OAS can provide a safe foundation in which the bedside staff can attend to both the spatter of sound peak events which might occur throughout the shift but also at peak times. The OAS level of the ventilatory equipment will mean the room is usually going to be in excess of the recommended sound levels, and thus the attuned nurse can ensure that parents and caregivers are near the infant so their voices can be detected by an infant for meaningful stimulation.

In the rush to ameliorate the lack of appropriate stimulation, future research must attend to the infant's exposure to the dynamic context of noise events, and consider how this effects the capacity to discriminate meaningful sound. Research into the significant role of maternal and caregiver voices¹⁰⁻¹² offers early evidence into the continuing value of family-centered strategies for promoting healthy neurodevelopment in medically complex newborn infants.

Conclusion

This study presents the first report of paediatric and neonatal intensive care and the step-down special care nursery setting in a paediatric hospital in Australia. We dispel the customary "noise is bad" notion by distinguishing both ongoing ambient sound and noise events. The contribution of both to the dynamic character of the hospital auditory environment supplies further insight about auditory experience for newborn infants in hospital.

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References

- 1 Corser N. Sleep of 1- and 2-Year-old Children in Intensive Care. *Issues Compr Pediatr Nurs* 1996;19:17-31.
- 2 Franco P, Montemitro E, Groswasser J. et al. Sleep disturbance in children resulting from noise exposure. In Sawaguchi, T, ed. *Sudden Infant Death Syndrome: From Pathophysiological Prospects*. Springer, Japan, 2014; 65-80.
- 3 deRegnier R, Wewerka S, Georgieff M, Mattia F, Nelson C. Influences of postconceptional age and postnatal experience on the development of auditory recognition memory in the newborn infant. *Dev Psychobiol* 2002;41:216-225.
- 4 Elliott R, McKinley S, Eager D. A pilot study of sound levels in an Australian adult general intensive care unit. *Noise Health* 2010;12:26.
- 5 Australasian Health Infrastructure Alliance. Australasian Health Facility Guidelines: Part B - Health Facility Briefing and Planning. 390 – Intensive Care- Neonatal / Special Care. Sydney: Australasian Health Infrastructure Alliance; 2014.
- 6 AS/NZS 2107:2000. Acoustics – Recommended design sound levels and reverberation in building interiors. [Internet]. [cited 2014 Sep 12]. Available from: <http://infostore.saiglobal.com/store/PreviewDoc.aspx?saleItemID=451191>
- 7 Noise: A Hazard for the Fetus and Newborn. *Pediatr* 1997;100:724-727.
- 8 White R, Smith J, Shepley M. Recommended standards for newborn ICU design, eighth edition. *J Perinatol* 2013;33:S2-S16.

- 9 Jobe A. A Risk of Sensory Deprivation in the Neonatal Intensive Care Unit. *J Pediatr* 2014;164:1265-1267.
- 10 Malloch S, Shoemark H, Črnčec R, et al. Music Therapy with hospitalised infants – the art and science of intersubjectivity. *Infant Ment Health J* 2012; 33:386-399.
- 11 Shoemark H. Frameworks for using music as a therapeutic agent for hospitalised newborn infants. In Rickard N, & McFerran K. eds. *Lifelong Engagement in Music: Benefits for Mental Health and Well-Being*, Nova Science Press, New York, 2013, 1-20.
- 12 Shoemark H, Arnup S. A survey of how mothers think about and use voice with their hospitalized newborn infant. *J Neonatal Nurs* 2014;20:115-121.
- 13 Gray PhD L. Properties of Sound. *J Perinatol* 2000;20:S6-S11.
- 14 Brandon D, Ryan D, Barnes A. Effect of Environmental Changes on Noise in the NICU. *Neonatal Netw* 2007;26:213-218.
- 15 Gray PhD L, Philbin RN PhD M. Measuring Sound in Hospital Nurseries. *J Perinatol* 2000;20:S100-S104.
- 16 Lasky R, Williams A. Noise and Light Exposures for Extremely Low Birth Weight Newborns During Their Stay in the Neonatal Intensive Care Unit. *Pediatr* 2009;123:540-546.
- 17 Wang D, Aubertin C, Barrowman N, Moreau K, Dunn S, Harrold J. Examining the effects of a targeted noise reduction program in a neonatal intensive care unit. *Arch Dis Child Fetal Neonatal Ed* 2013;99:F203-F208.
- 18 Philbin M, Robertson A, Hall J. Recommended Permissible Noise Criteria for Occupied, Newly Constructed or Renovated Hospital Nurseries. *J Perinatol* 1999;19:559-563.

- 19 Kuhn P, Zores C, Pebayle T, Hoeft A, Langlet C, Escande B et al. Infants born very preterm react to variations of the acoustic environment in their incubator from a minimum signal-to-noise ratio threshold of 5 to 10 dBA. *Pediatr Res* 2012;71:386-392.
- 20 Liu W. Comparing sound measurements in the single-family room with open-unit design neonatal intensive care unit: the impact of equipment noise. *J Perinatol* 2011;32:368-373.

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Table 1 OAS levels in the old and new hospital

	Old n=38			New n=42		
Recommended levels	SCN n=9	NICU n=10	PICU n=19	SCN n=10	NICU n=15	PICU n=17
L_{eq} (45dBA)	61	58	61	60	60	63
L_{max} (65dBA)	65	62	64	64	63	65
L_{min} (<40dBA)	56	55	58	55	57	62

Table 2: Changes in OAS environment

	New compared to Old (95% CI, p value)	PICU compared to NICU (95% CI, p value)	SCN compared to NICU (95% CI, p value)
L_{eq} (45 dBA)	-2.6 (-5.5 to 0.3), p=0.8	-0.2 (-3.7 to 3.2), p=0.9	-5.9 (-10.3 to -1.5), p=0.01
L_{max} (65 dBA)	-3.4 (-6.4 to -0.4), p=0.03	0.0 (-3.6 to 3.6), p>0.9	-5.1 (-9.8 to -0.4), p=0.03
L_{min} (<40 dBA)	2.7 (-0.1 to 5.5), p=0.06	0.3 (-2.9 to 3.5), p=0.8	-7.7 (-11.4 to -4.0), p<0.001

Estimates obtained from a linear regression model using log-transformed pascals and including hospital and unit as covariates. Estimates were back-transformed to dBA.

Table 3: Number of events and duration of events between old and new hospital and between units

	Old (ref)	New	Rate ratio (95% CI) p-value	NICU (ref)	SCN	Rate ratio (95% CI) p-value	PICU	Rate ratio (95% CI) p-value
>65dBA								
number of events - median [IQR]	334 [256 - 403]	271 [212 - 304]	0.82 (0.73 to 0.92) p=0.001	283 [235 - 320]	256 [224 - 280]	0.89 (0.76 to 1.0) p=0.1	338 [245 - 420]	1.1 (0.98 to 1.3) p=0.09
SP events								
number of events - median [IQR]	29 [13-67]	126 [73-366]	4.1 (2.8 to 5.9) p<0.0001	42 [29-43]	226 [153- 540]	5.8 (3.6 to 9.5) p<0.0001	46 [14- 108]	0.9 (0.6 to 1.3) p=0.5

Table 4 Effect of ventilation equipment on the OAS and rate of noise events

	Old n=29		New n=32		Equipment - No Equipment	
Recommended levels*	Equipment n=24	No equipment n=5	Equipment n=21	No equipment n=11	Difference (95% CI)	p- value
L_{eq} (45dBA)	60	61	64	60	2.1 (0.6 to 3.6)	0.01
L_{max} (65dBA)	63	65	63	65	1.7 (0.5 to 2.9)	0.01
L_{min} (<40dBA)	57	57	57	63	1.8 (0.5 to 3.2)	0.01
Noise Events^					Rate Ratio (95% CI)	p- value
>65dBA L_{max} - Median [IQR]	378 [284 - 406]	435 [312 - 458]	302 [250 - 321]	218 [201 - 274]	1.1 (0.98 to 1.3)	0.1
SP events - Median [IQR]	18 [13 - 30]	39 [14 - 53]	73 [43 - 116]	129 [106 - 353]	0.47 (0.28 to 0.79)	0.005

*Differences, 95% CI and p-values are obtained from a linear regression model using log-transformed pascals and included hospital and unit as covariates. Estimates were back-transformed to dBA.

^Rate ratio was estimated from a linear regression model using log-transformed rate of events and included hospital and unit as covariates

Table 5: Comparison between day and night of OAS levels and rate of noise events

	Old n=38		New n=48		Day - Night	
Recommended levels*	Day	Night	Day	Night	Difference (95% CI)	p-value
L_{eq} (45dBA) - Mean	61	59	62	59	3.3 (2.8 to 3.8)	<0.001
L_{max} (65dBA) - Mean	64	62	65	56	2.9 (2.4 to 3.3)	<0.001
L_{min} (<40dBA) - Mean	57	56	61	55	1.8 (1.4 to 1.6)	<0.001
Noise Events^					Rate Ratio (95% CI)	p-value
>65dBA L_{max} - Median [IQR]	10 [7 - 13]	15 [13 - 18]	9 [6 - 11]	12 [10 - 14]	1.6 (1.4 to 1.7)	<0.001
SP events - Median [IQR]	1 [1-3]	1 [1-3]	4 [2-18]	6 [3-14]	1.1 (0.94 to 1.3)	0.2

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The sound environment was surveyed for 24 hour data collection periods ($n=80$) in the Neonatal and Paediatric Intensive Care Units (NICU and PICU) and Special Care Nursery (SCN) of the old and new Royal Children's Hospital Melbourne.

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In the old hospital none of the data collection periods in the NICU and PICU met the standard benchmark for ongoing ambient sound, while only 5 of the 22 data collection periods in the new hospital met the recommended level. There was no change in proportion of time at recommended L_{eq} between the old and the new SCN. There was strong evidence for a difference in the mean number of events $>65\text{dBA}$ (L_{max}) in the old and new hospital (rate ratio = 0.82, 95% CI: 0.73 to 0.92, $p=0.001$). The NICU and PICU were above 50dBA in 75% of all data collection periods, with ventilatory equipment associated with higher ongoing ambient sound levels.

Conclusions

The OAS suggests that the background sound environment of the new hospital is not different to the old hospital. However, there may be a reduction in the number of noise events.

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Introduction

The ambient sound environment of intensive care settings may alter the sleep states of infants and children^{1,2} and may modulate long-term neurodevelopmental outcome³. In paediatric healthcare, medically complex newborn infants are cared for in diverse settings including Neonatal Intensive Care Units (NICU), Special Care Nurseries (SCN) and Paediatric Intensive Care Units (PICU). These settings are culturally specific with variation in the physical space, service delivery, and provisions for care and family's experience. To date, the only published study of ICU auditory environments in Australian healthcare has been for a general adult intensive care unit⁴.

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We measured the sound environment in three hospital settings where critically ill newborn infants are cared for: NICU, SCN and PICU units. The ongoing ambient sound was benchmarked against the Australian standards for L_{eq} , L_{max} and L_{min} . Noise events, defined below, were characterized as $>65\text{dBA } L_{max}$, and sound peak events. The study was approved by the Human Research Ethics Committee.

Study design and data collection

In the old hospital, the PICU contained 7 rooms with 4 – 5 beds per room, and one room with one bed. The NICU and SCN were co-located in a refurbished ward, with 5 rooms containing 4 beds, and two rooms containing 2 beds. In the new hospital, the PICU and NICU had 30 and 12 individual rooms respectively, arranged as pairs of rooms divided by a

sliding glass door. The SCN had 7 two-bed rooms arranged in pairs of rooms divided by a sliding glass door. Because of the disparity in room sizes between wards and between the old and new hospital, equitable area measurements were not possible. Instead, individualized bed measurements were made at approximately the same distance from the infant in each bed position. Data were collected for a single 24 hour period to capture the variation in the auditory environment across a full day^{14,15}. All measurements were in open air (none inside incubators).

Loudness data were collected with a Class 1 Quest SoundPro DL Sound Level Meter (SLM) (Quest Technologies) set for A-weighted slow response mode (dBA Slow) as specified for the standard benchmarks. The sound level was recorded in 5-second epochs¹⁵. The microphone (Class I BK4936, Brüel & Kjær) was isolated from the SLM using a one metre extension lead connected to the microphone. A microphone stand and boom arm were used to place the recording microphone at the head-end of the patient's bed, as close to the patient's head as could safely be achieved. The SLM was calibrated at the commencement of each data collection against a 1kHz 114dB pure tone from the manufacturer's acoustic calibrator (QC-10). Equipment in use at the time of recording was catalogued for the individual bed, and for adjacent bed spots in the area of recording¹⁶. Equipment was grouped as ventilators or infusion pumps (feed, syringe and volumetric).

Data was collected in every occupied bed in each unit in both hospitals. The SLM data was stored on removable storage cards and transferred to a central database (QuestSuite Professional II version 5.0.2317).

Analysis

The OAS was measured with the mean 5-sec L_{eq} , L_{max} and L_{min} ¹³ and the proportion of time in the 24 hour data collection period (DCP) where the L_{eq} was equal to or less than the benchmark of 45 dBA_{slow}. The change in mean L_{eq} , L_{max} and L_{min} , 95% confidence interval (CI) and p-value between hospital and unit was estimated from a linear regression model fit with log-pascals and back transformed to dBA for presentation. The difference in the proportion of time in the DCP where the L_{eq} was less than the benchmark of 45 dBA is assessed with the Kruskal-Wallis equality-of-populations rank test.

Two types of noise events were measured¹⁷. First, the >65dBA L_{max} events commenced with any recording of 65dBA or greater and ceased when the sound reduced below 65dBA for at least 40 seconds; and second, the Sound Peak (SP) events were defined as a jump of at least 12dBA between two consecutive 5 second readings in the L_{eq} to identify detectable events for newborn infants.

For each noise event we present the median and inter quartile range (IQR) of the number of events for the old and new hospital, and for each of the units. The data were log-transformed and we used linear regression to estimate the mean percentage increase between hospitals and units, as well as the 95% CI and p-value for that increase. The duration of event is discussed descriptively only as the data were strongly skewed.

Additionally, for each outcome measure we assessed the evidence for a difference between rooms with and without equipment and between day (7:00 to 22:59) and night (23:00 to

6:59) using linear regression as above. All analyses were performed in Stata 13 (StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP).

Results

Ongoing ambient sound

The OAS environment of all units in both the old and new hospitals exceeded the L_{eq} and L_{max} levels stipulated by the Consensus Committee for NICU Design (Table 1). The L_{min} levels which provided a sound “floor” for the OAS not only exceeded the benchmark for L_{min} , but also for the L_{eq} .

[Insert Table 1. OAS levels in the old and new hospital]

Table 2 shows the estimated change in the OAS environment between the old and new hospital, after accounting for unit, and between units after accounting for hospital.

[Insert Table 2. Changes in OAS environment]

In the old hospital, no DCPs in the NICU and PICU met the recommended L_{eq} , while in the new hospital the L_{eq} was only below 45 dBA in 5 of the 22 DCPs. The median proportion of time below 45dBA in those 5 cases was 6% [range 2% to 41%]. In the SCN, there was no evidence that the proportion of time at the recommended L_{eq} differed between the old

and the new hospital (old: median 20% [IQR 17% to 29%]; new: median 28% [IQR 23% to 37%], $p = 0.12$).

Noise events

The number of each type of noise event is shown in Table 3.

$L_{\max}$ Noise events (over 65dBA)

There was a decrease in the mean number of $L_{\max}$ events from the old and new hospital (rate ratio = 0.82, 95% CI: 0.73 to 0.92, $p=0.001$). There was no evidence for a difference in the number of $L_{\max}$ events between the NICU and SCN, and between NICU and PICU however there was strong evidence that PICU had more events than the SCN (rate ratio = 1.26, 95% CI: 1.10 to 1.45, $p = 0.001$) (see Table 3).

The duration of noise events across the data was strongly skewed. In 50% of the events in both hospitals and each unit the duration of events was less than 55 seconds (IQR: 40 seconds to 85 seconds, max: 41 minutes).

[Insert Table 3: Number of events between old and new hospital and between units]

Sound Peak events (12dBA jump)

In all units, the number of SP events was observed to be larger in the new hospital than in the old hospital. The new hospital was estimated to have 4.1 (95% CI: 2.8 to 5.9, $p < 0.001$) times the number of events. The number of events was observed to be greatest in the SCN,

which was estimated to have 5.8 (95% CI: 3.6 to 9.5, $p < 0.001$) times the number of events as the NICU. There was no evidence for a difference in the number of events between NICU and PICU (Rate ratio 0.9, 95% CI: 0.6 to 1.3, $p = 0.5$).

Effect of equipment in room

The only equipment present in the SCN are infusion pumps. Therefore we investigated the effect of mechanical ventilation equipment only in the NICU and PICU. There was some evidence for a difference in the OAS between rooms with and without ventilation equipment, although the magnitude was small.

[Insert Table 4 Effect of ventilation equipment on the OAS]

There was no evidence for a difference in the rate of $>65\text{dBA}$ noise events in rooms with and without equipment, however there was moderate evidence that the rate of SP events decreased in rooms with equipment by 53% (rate ratio= 0.47 (95%CI: 0.28 to 0.79, $p=0.01$))

There was little change in the duration of $>65\text{dBA}$ $L_{\max}$ events in both hospitals and both units, with at most a median difference of 5 seconds between rooms with and without equipment.

Day and night

There was no evidence for a difference in OAS between day and night in the OAS of the old and new hospital (Table 5).

[Insert Table 5 OAS levels day vs night]

There was strong evidence for a difference in the rate of $>65\text{dBA } L_{\text{max}}$ events between day and night (rate ratio = 1.6, 95%CI: 1.4 to 1.7, $p < 0.001$), but not in SP events. There was little change in the duration of $>65\text{dBA } L_{\text{max}}$ events in both hospitals and both units, with at most a median difference of 5 seconds between day and night events.

Discussion

In a comparison of the old and new hospitals, there was no evidence for a significant difference in OAS. This unexpected finding tests the idea that newer building fabrics and design would change the overall sound environment, but confirms previous findings that dynamic human activity such as nursing care and medical treatment cause significant noise.

Measurement of the customary markers for ongoing sound levels (L_{eq} , L_{10} and L_{max}), showed no evidence that the new hospital was quieter than the old hospital.

Overall the NICU and PICU exceeded not only the L_{eq} benchmark of 45 dBA most of the time, but also the benchmark of L_{10} 50dBA, which should be exceeded only 10% of the time.

The comparison of the OAS suggests that the sound environment of the new hospital is not different. However by considering both ongoing ambient sound and noise events, there is evidence of improvement. In both hospitals there was evidence that the number of 65dBA noise events is higher in the PICU than the SCN. However after accounting for the effect of the unit, there is still strong evidence that the new hospital has fewer noise events above the $L_{\max}$ level of 65dBA, supporting a benefit of individual rooms. This is confirmed by the finding that in the SCN there were more SP events (a jump of 12dBA) than in the NICU and PICU. The SCN in the new hospital continues to house two beds in each room with less space between beds than in the old hospital. Noise from adjacent beds and rooms are likely to have contributed to the increased number of SP events recorded in this setting.

Analysis of the NICU and PICU rooms with and without ventilators revealed similar patterns of high ongoing ambient levels, the main effect of equipment being a 24 hour sound “floor” well above 50dBA in 87% of rooms with equipment. We did report the expected patterns with OAS reducing overnight. However the lower OAS overnight leaves the environment more vulnerable to SP noise events which are believed to disrupt infant sleep¹³.

The existing recommendations for L_{eq} , L_{10} and $L_{\max}$ have provided important benchmarks for noise in intensive care environments. However, studies across the last 10 years have shown that the levels are generally not attainable in a functioning NICU^{16,17}. The original bases for existing recommendations included the minimisation of sleep disruption and interference in speech intelligibility among adults¹⁸. The signal-to-noise ratio of the speech

intelligibility assumed a distance of 12 feet (3.7 meters) between nurses in an open bay unit (i.e., nurses able to hear each other speaking at normal loudness level at a distance of 12 feet). In the single or even double bed rooms of the modern hospital the distance between nurses is reduced by the physical dimensions of the room, or by the use of wireless handset devices between nurses. Therefore speech intelligibility may no longer be a relevant determinant in modern intensive care units. Consideration of recent studies might inform a review of both the American and Australian standards to produce more useful guidelines for the functioning intensive care environments.

Aligned with Kuhn's findings¹⁹ for very preterm infants, we postulate that repeated exposure to sudden onset and dramatic noise events (such as $L_{\max}$ and SP events) is more likely to cause disruption to sleep and should therefore be a key consideration in further research.

The traditional focus on attenuating ambient sound has recently been counter-balanced by reports of poorer neurodevelopmental outcomes for preterm infants cared for in single rooms²⁰. In practice, attention to the OAS can provide a safe foundation in which the bedside staff can attend to both the spatter of sound peak events which might occur throughout the shift but also at peak times. The OAS level of the ventilatory equipment will mean the room is usually going to be in excess of the recommended sound levels, and thus the attuned nurse can ensure that parents and caregivers are near the infant so their voices can be detected by an infant for meaningful stimulation.

In the rush to ameliorate the lack of appropriate stimulation, future research must attend to the infant's exposure to the dynamic context of noise events, and consider how this effects the capacity to discriminate meaningful sound. Research into the significant role of maternal and caregiver voices¹⁰⁻¹² offers early evidence into the continuing value of family-centered strategies for promoting healthy neurodevelopment in medically complex newborn infants.

Conclusion

This study presents the first report of paediatric and neonatal intensive care and the step-down special care nursery setting in a paediatric hospital in Australia. We dispel the customary "noise is bad" notion by distinguishing both ongoing ambient sound and noise events. The contribution of both to the dynamic character of the hospital auditory environment supplies further insight about auditory experience for newborn infants in hospital.

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References

- 1 Corser N. Sleep of 1- and 2-Year-old Children in Intensive Care. *Issues Compr Pediatr Nurs* 1996;19:17-31.
- 2 Franco P, Montemitro E, Groswasser J. et al. Sleep disturbance in children resulting from noise exposure. In Sawaguchi, T, ed. *Sudden Infant Death Syndrome: From Pathophysiological Prospects*. Springer, Japan, 2014; 65-80.
- 3 deRegnier R, Wewerka S, Georgieff M, Mattia F, Nelson C. Influences of postconceptional age and postnatal experience on the development of auditory recognition memory in the newborn infant. *Dev Psychobiol* 2002;41:216-225.
- 4 Elliott R, McKinley S, Eager D. A pilot study of sound levels in an Australian adult general intensive care unit. *Noise Health* 2010;12:26.
- 5 Australasian Health Infrastructure Alliance. Australasian Health Facility Guidelines: Part B - Health Facility Briefing and Planning. 390 – Intensive Care- Neonatal / Special Care. Sydney: Australasian Health Infrastructure Alliance; 2014.
- 6 AS/NZS 2107:2000. Acoustics – Recommended design sound levels and reverberation in building interiors. [Internet]. [cited 2014 Sep 12]. Available from: <http://infostore.saiglobal.com/store/PreviewDoc.aspx?saleItemID=451191>
- 7 Noise: A Hazard for the Fetus and Newborn. *Pediatr* 1997;100:724-727.
- 8 White R, Smith J, Shepley M. Recommended standards for newborn ICU design, eighth edition. *J Perinatol* 2013;33:S2-S16.
- 9 Jobe A. A Risk of Sensory Deprivation in the Neonatal Intensive Care Unit. *J Pediatr* 2014;164:1265-1267.
- 10 Malloch S, Shoemark H, Črnčec R, et al. Music Therapy with hospitalised infants – the art and science of intersubjectivity. *Infant Ment Health J* 2012; 33:386-399.

- 11 Shoemark H. Frameworks for using music as a therapeutic agent for hospitalised newborn infants. In Rickard N, & McFerran K. eds. *Lifelong Engagement in Music: Benefits for Mental Health and Well-Being*, Nova Science Press, New York, 2013, 1-20.
- 12 Shoemark H, Arnup S. A survey of how mothers think about and use voice with their hospitalized newborn infant. *J Neonatal Nurs* 2014;20:115-121.
- 13 Gray PhD L. Properties of Sound. *J Perinatol* 2000;20:S6-S11.
- 14 Brandon D, Ryan D, Barnes A. Effect of Environmental Changes on Noise in the NICU. *Neonatal Netw* 2007;26:213-218.
- 15 Gray PhD L, Philbin RN PhD M. Measuring Sound in Hospital Nurseries. *J Perinatol* 2000;20:S100-S104.
- 16 Lasky R, Williams A. Noise and Light Exposures for Extremely Low Birth Weight Newborns During Their Stay in the Neonatal Intensive Care Unit. *Pediatr* 2009;123:540-546.
- 17 Wang D, Aubertin C, Barrowman N, Moreau K, Dunn S, Harrold J. Examining the effects of a targeted noise reduction program in a neonatal intensive care unit. *Arch Dis Child Fetal Neonatal Ed* 2013;99:F203-F208.
- 18 Philbin M, Robertson A, Hall J. Recommended Permissible Noise Criteria for Occupied, Newly Constructed or Renovated Hospital Nurseries. *J Perinatol* 1999;19:559-563.
- 19 Kuhn P, Zores C, Pebayle T, Hoeft A, Langlet C, Escande B et al. Infants born very preterm react to variations of the acoustic environment in their incubator from a minimum signal-to-noise ratio threshold of 5 to 10 dBA. *Pediatr Res* 2012;71:386-392.
- 20 Liu W. Comparing sound measurements in the single-family room with open-unit design neonatal intensive care unit: the impact of equipment noise. *J Perinatol* 2011;32:368-373.

Table 1 OAS levels in the old and new hospital

	Old n=38			New n=42		
Recommended levels	SCN n=9	NICU n=10	PICU n=19	SCN n=10	NICU n=15	PICU n=17
L_{eq} (45dBA)	61	58	61	60	60	63
L_{max} (65dBA)	65	62	64	64	63	65
L_{min} (<40dBA)	56	55	58	55	57	62

Table 2: Changes in OAS environment

	New compared to Old (95% CI, p value)	PICU compared to NICU (95% CI, p value)	SCN compared to NICU (95% CI, p value)
L_{eq} (45 dBA)	-2.6 (-5.5 to 0.3), p=0.8	-0.2 (-3.7 to 3.2), p=0.9	-5.9 (-10.3 to -1.5), p=0.01
L_{max} (65 dBA)	-3.4 (-6.4 to -0.4), p=0.03	0.0 (-3.6 to 3.6), p>0.9	-5.1 (-9.8 to -0.4), p=0.03
L_{min} (<40 dBA)	2.7 (-0.1 to 5.5), p=0.06	0.3 (-2.9 to 3.5), p=0.8	-7.7 (-11.4 to -4.0), p<0.001)

Estimates obtained from a linear regression model using log-transformed pascals and including hospital and unit as covariates. Estimates were back-transformed to dBA.

Table 3: Number of events and duration of events between old and new hospital and between units

	Old (ref)	New	Rate ratio (95% CI) p-value	NICU (ref)	SCN	Rate ratio (95% CI) p-value	PICU	Rate ratio (95% CI) p-value
>65dBA								
number of events - median [IQR]	334 [256 - 403]	271 [212 - 304]	0.82 (0.73 to 0.92) p=0.001	283 [235 - 320]	256 [224 - 280]	0.89 (0.76 to 1.0) p=0.1	338 [245 - 420]	1.1 (0.98 to 1.3) p=0.09
SP events								
number of events - median [IQR]	29 [13-67]	126 [73-366]	4.1 (2.8 to 5.9) p<0.0001	42 [29-43]	226 [153-540]	5.8 (3.6 to 9.5) p<0.0001	46 [14-108]	0.9 (0.6 to 1.3) p=0.5

Table 4 Effect of ventilation equipment on the OAS and rate of noise events

	Old n=29		New n=32		Equipment - No Equipment	
Recommended levels*	Equipment n=24	No equipment n=5	Equipment n=21	No equipment n=11	Difference (95% CI)	p- value
L_{eq} (45dBA)	60	61	64	60	2.1 (0.6 to 3.6)	0.01
L_{max} (65dBA)	63	65	63	65	1.7 (0.5 to 2.9)	0.01
L_{min} (<40dBA)	57	57	57	63	1.8 (0.5 to 3.2)	0.01
Noise Events^					Rate Ratio (95% CI)	p- value
>65dBA L_{max} - Median [IQR]	378 [284 - 406]	435 [312 - 458]	302 [250 - 321]	218 [201 - 274]	1.1 (0.98 to 1.3)	0.1
SP events - Median [IQR]	18 [13 - 30]	39 [14 - 53]	73 [43 - 116]	129 [106 - 353]	0.47 (0.28 to 0.79)	0.005

*Differences, 95% CI and p-values are obtained from a linear regression model using log-transformed pascals and included hospital and unit as covariates. Estimates were back-transformed to dBA.

^Rate ratio was estimated from a linear regression model using log-transformed rate of events and included hospital and unit as covariates

Table 5: Comparison between day and night of OAS levels and rate of noise events

	Old n=38		New n=48		Day - Night	
Recommended levels*	Day	Night	Day	Night	Difference (95% CI)	p-value
L_{eq} (45dBA) - Mean	61	59	62	59	3.3 (2.8 to 3.8)	<0.001
L_{max} (65dBA) - Mean	64	62	65	56	2.9 (2.4 to 3.3)	<0.001
L_{min} (<40dBA) - Mean	57	56	61	55	1.8 (1.4 to 1.6)	<0.001
Noise Events^					Rate Ratio (95% CI)	p-value
>65dBA L_{max} - Median [IQR]	10 [7 - 13]	15 [13 - 18]	9 [6 - 11]	12 [10 - 14]	1.6 (1.4 to 1.7)	<0.001
SP events - Median [IQR]	1 [1-3]	1 [1-3]	4 [2-18]	6 [3-14]	1.1 (0.94 to 1.3)	0.2

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L_{max} (65 dBA)	-3.4 (-6.4 to -0.4), p=0.03	0.0 (-3.6 to 3.6), p>0.9	-5.1 (-9.8 to -0.4), p=0.03
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SP events - Median [IQR]	1 [1-3]	1 [1-3]	4 [2-18]	6 [3-14]	1.1 (0.94 to 1.3)	0.2

*Differences, 95% CI and p-values are obtained from a linear regression model using log-transformed pascals and included hospital and unit as covariates. Estimates were back-transformed to dBA.

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