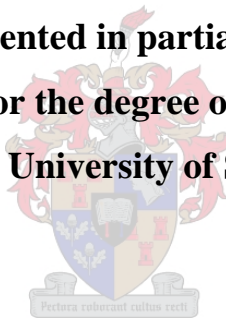


**NOISE LEVELS IN A NEONATAL INTENSIVE CARE
UNIT IN THE CAPE METROPOLE**

Lisa Nathan

**Thesis presented in partial fulfilment of the
requirements for the degree of Master of Audiology
at the University of Stellenbosch**



Professor S.K. Tuomi

Mrs A.M.U. Muller

December 2007

DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature: _____

Date: _____

ABSTRACT

Noise is a noxious stimulus with possible negative physiological effects on the infant, especially in the Neonatal Intensive Care Unit (NICU). The present study conducted a detailed noise assessment in a NICU of a state hospital in the Cape Metropole and documented 6 infants' physiological responses to noise levels. Noise levels ranged from 62.3-66.7dBA (L_{Aeq}), which exceed all American and British standards (50dBA - 60dBA) for a NICU. Continuous exposure to noise of these levels is potentially harmful to the infants' auditory system and health stability. The general well-being of the staff working in the NICU may also be compromised. Analysis of the noise events revealed that staff conversations were the largest single contributor to the number of noise events, while the largest single non-human contributor was the alarm noise of the monitors. No significant correlations were found between the heart rates and noise levels and the respiratory rates and the noise levels for any of the participants in either room. The NICU was found to be an extremely reverberant environment, which suggested that the NICU noise levels were largely a result of reverberant noise reinforcements. NICU nursing staff's most common suggestion for noise abatement strategies was reduction of staff conversation. Results of this study highlight the need for NICU noise abatement to optimise newborn patient care, reduce the risk of acoustic trauma and to improve the neonate's quality of life, thus enhancing the infant's physiologic stability, growth and health.

Keywords: neonatal intensive care unit; NICU; noise; noise levels; reverberation

ABSTRAK

Lawaai is 'n skadelike stimulus met moontlike negatiewe fisiologiese effekte op die pasgebore baba, veral in die Neonatale Intensiewesorgeenheid (NISE). Die studie het 'n noukeurige meting van lawaai in die NISE van 'n staatshospitaal in die Kaapse Metropool behels, en die fisiologiese response van 6 babas op lawaaivlakke gedokumenteer. Die lawaaivlakke was tussen 62.3 - 66.7dBA (L_{Aeq}), wat beide Amerikaanse en Britse standaarde (50dBA - 60dBA) vir 'n NISE oorskry het. Langdurige blootstelling aan sulke lawaaivlakke kan potensiëel skadelik wees vir die baba se gehoorsisteem en stabiliteit van gesondheid. Die algemene welsyn van die personeel wat in die NISE werk mag ook benadeel word. 'n Analise van lawaaigebeure het aangetoon dat die gesprekke van die personeel die grootste bydraende faktor was van al die lawaaigebeure, terwyl die grootste nie-menslike bydraende faktor die alarmlawaai van die monitors was. Geen beduidende korrelasies is egter gevind tussen die hart- en asemhalingstempo's en die lawaaivlakke van enige van die proefpersone in die twee kamers nie. Daar is gevind dat die NISE 'n uiters reverberante omgewing is, wat daarop dui dat die lawaaivlakke in die NISE grootliks die gevolg van reverberasie lawaaiversterkings is. Die mees algemene voorstel van die NISE se personeel vir lawaaibeperking was 'n vermindering van die personeel se gesprekke. Resultate van hierdie studie beklemtoon die behoefte vir NISE lawaaivermindering om die baba se versoring te optimaliseer, die risiko van akoestiese trauma te verminder, en om die kwaliteit van lewe van die neonaat te verbeter, om sodoende fisiologiese stabiliteit, groei en gesondheid te verbeter.

Hoofwoorde: Neonatale Intensiewesorgeenheid; NICU; lawaai; lawaaivlakke; reverberant

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“Alone we can do so little; together we can do so much” - Helen Keller

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1. INTRODUCTION

1.1 INTRODUCTION

The Neonatal Intensive Care Unit (NICU) is “home” to many premature and full-term newborn infants whose wellbeing requires critical care, for weeks or even months at a time. Technological advances and improved understanding of the neonatal condition have reduced infant mortality and infants are spending longer periods as in-patients in the NICU. However, the improvements in neonatal care have been accompanied by concerns over the impact of the NICU environment on these infants.

Noise is everywhere in our environment and even more so in the technology backed environment of NICU. Unfortunately, NICU noise has been found to be a major source of environmental stress for the neonate (Blackburn, 1998). Numerous published studies have measured noise levels that would be considered dangerous to adults working in a noisy workplace (Benini, Magnavita, Lago, Arslan & Pisan, 1996; Blackburn, 1998; Byers, Waugh & Lowman, 2006; Elander & Hellström, 1995; Gray, Dostal, Ternullo-Retta & Armstrong, 1998; Hoehn, Busch & Krause, 2000; Kent, Tan Clarke & Bardell, 2002; Morris, Philbin & Bose, 2000; Nzama, Nolte & Dörfling, 1995; Robertson, Kohn, Vos & Cooper-Peel, 1998; Strauch, Brandt & Edwards-Beckett, 1993).

The effects of noise on the fragile infants in the NICU have been well researched, particularly the cardiovascular and respiratory effects. Studies have been conducted that documenting the effect of the noise on the infant’s auditory system such as noise-induced sensorineural hearing impairment (usually mild to moderate in severity). Some research has also suggested that attention-related difficulties and information processing disorders at pre- and school-going ages as well as speech delays, language-related problems and learning difficulties might be due to noise exposure at NICU (Graven, 2000; Weisglas-Kuperus, Baerts, de Graaf, van Zanten & Sauer, 1993).

To date, limited studies have been conducted in South Africa relating to noise in the NICU, such as the study by Nzama et al., 1995. It was conducted at a private clinic in

Gauteng and sought to identify noise sources and measure the noise levels in the NICU in order to provide guidelines for reducing or preventing noise in NICUs.

Research in the area of noise in the NICU and its effects highlights the need for NICU noise reduction, which should be a vital part of optimising newborn patient care to improve the neonates' quality of life, contribute to their physiologic stability and enhance growth and health in the neonates in the NICU. So the purpose of this study was to provide an index of the existing noise levels in one state hospital in the Cape Metropole, noise sources and potential physiological responses of the infants to the noises as well as to give guidelines to whether stricter noise management is required.

1.2 FORM OF THESIS

This thesis is divided into the following chapters:

- Chapter 1 – Introduction - States the nature and scope of the study, orientating the reader. A glossary of terms is included in this chapter, which provides a brief description of some of the key terms and abbreviations used in the research project.
- Chapter 2 - Literature Review - Reviews the literature, summarizes previous research and provides a background of the field under investigation.
- Chapter 3 – Methodology - States the procedures and protocols that were used and followed during the research project.
- Chapter 4 – Results and Discussion - Discusses the outcomes of the study.
- Chapter 5 - Conclusions, Critique and Implications - It compares the aims with the achievements, provides a critique of certain aspects of the study and suggests a number of future developments.
- References lists all material cited in this report.
- Appendices, contains supplementary information and data.

1.3 GLOSSARY OF TERMS

A-weight: A standard frequency weighting to simulate the response of the human ear (Larson Davis, 1999, p.B1).

Calibration: Adjustment of the system so that the measured sound level agrees with a reference sound source (Larson Davis, 1999, p.B1).

Decibel (dB): One-tenth of a bel; unit of sound intensity, based on a logarithmic relationship of one intensity to a reference intensity. The decibel scale starts at 0 dB for sounds that can just be heard and reaches 130 dB at the onset of aural pain (Stach, 2003, p.75).

dBA: decibels expressed in sound pressure level as measured on the A-weighted scale of sound level meter filtering network; used in the measurement of environmental noise (Stach, 2003, p.76)

Exchange rate: is defined as the change in sound level corresponding to a doubling or halving of the duration of sound level while a constant percentage of criterion exchange is maintained. Possible values for this field are 3, 4, 5 or 6. A value of 3 will produce L_{eq} -like levels (Larson Davis, 1999, p.B2).

L_{Aeq} : Equivalent continuous sound level (using A-weighted sound level) over the elapsed measurement time. This is the most useful parameter for giving an impression of the average sound pressure level (Brüel & Kjær, 2001, p.25).

L_n : The A-weighted sound level, in decibels, that is exceeded n percent of the time in a given interval of time...The default L_n percentages are 10, 30, 50, 70 or 90... L_{00} is the same as the maximum sound level since it was the level exceeded 0% of the time (Larson Davis, 1999, p.B2).

MaxL: Maximum sound pressure level (SPL) over the elapsed measurement time (Brüel & Kjær, 2001, p.26).

MinL: Minimum sound pressure level (SPL) over the elapsed measurement time (Brüel & Kjær, 2001, p.26).

Neonatal intensive care: care for medically unstable or critically ill newborns requiring constant nursing, complication surgical procedures, continual respiratory support or other intensive interventions (Fifth Consensus Conference on Newborn ICU Design, 2002, p.7)

Noise: is a sound which disturbs or may disturb or impair the convenience or piece of any person (Turkington & Sussman, 2000, p.151).

Peak: The maximum peak level within the last one second interval (Brüel & Kjær, 2001, p.26)

Premature: A premature infant is any infant born before 37 weeks gestation (alternative name: preterm) (MedlinePlus Medical Encyclopedia, 2004, p.1).

Reverberation: the prolongation of sound by multiple reflections (Stach, 2003, p.231).

Reverberation time: It is the time required for a sound that is very loud to decay to inaudibility (Alton Everest, 2001, p.135)

Sound: Sound is a vibration in a medium, usually air, and has the properties of intensity (loudness), frequency (pitch), periodicity and duration (American Academy of Pediatrics, 1997).

SPL: The maximum sound pressure level within the last one second interval. This parameter is different from the peak value because SPL is an RMS (root mean square) measurement (Brüel & Kjær, 2001, p.26).

2. LITERATURE REVIEW

2.1 PRENATAL DEVELOPMENT OF THE EAR AND HEARING

The human auditory system is one of the last of the senses, besides vision, to develop during gestation (White-Traut, Nelson, Burns & Cunningham, 1994; Hall, 2000ii). By the third trimester, the tactile, olfactory, vestibular and gustatory pathways are developed, whilst the visual and auditory pathways are still immature and vulnerable (D'Agostino & Clifford, 1998). The development of the cochlea and peripheral auditory sensory end organs is complete by 24 weeks gestation whereas maturation of the auditory pathways of the central nervous system (CNS) continues up to 42 weeks gestation (Hall, 2000ii; Passchier-Vermeer, 2000). Detection of an auditory stimulus by the human fetus from outside its mother occurs during the beginning of the third trimester, provided that the cochlea and the neural pathways are functional (Abrams & Gerhardt, 2000).

The mother's voice is the most common and important mode of potential auditory stimulation for the fetus (Abrams & Gerhardt, 2000). The fetus' ability to discriminate voice and capacity for auditory discrimination is present prior to 35 weeks gestation (Gardner & Goldson, 2002; Moon & Fifer, 2000). Exposure to maternal speech in-utero is thought to be a factor for later language and speech development (Hepper, Scott & Shahidullah, 1993; Ruben, 1992). The newborn's ability to recognise and discriminate the mother's voice also plays a role in the mother-infant attachment process (Graven, 2000).

In addition to the mother's voice, the fetus is bombarded with many other sounds in utero. Studies have revealed that background noise in the uterus is more than 50dBSPL with short bursts over 70dBSPL in the low frequencies (<250Hz) (Gerhardt & Abrams, 2000; Graven, 2000). Internal sounds from maternal respiratory, cardiovascular and intestinal sources are "*continuous sounds...punctuated by isolated short bursts during maternal body movements and vocalisations*" (Abrams & Gerhardt, 2000, p.S31). External sources of ambient noise may increase the level of in-utero background noise but the tissues surrounding the uterus provide attenuation of frequencies higher than 250Hz, thus protecting the developing auditory system (D'Agostino & Clifford, 1998).

Besides the detection of auditory stimuli, Hall (2000ii) explains that as early as 23-25 weeks gestation, the auditory system of the human fetus is mature enough to produce physiologic effects to sound. Sudden bursts of intense sound of >70dB SPL have been found to increase fetal heart rate, respiration, oxygen consumption, blood pressure, glucose consumption and movement (Abrams & Gerhardt, 2000; Gerhardt & Abrams, 2000; Graven, 2000).

2.2 EXPOSURE TO SOUND AFTER BIRTH

For all newborns, exposure to sound outside the womb is significantly different from the in-utero experience, because the natural attenuation of the higher frequencies by the uterus tissues is no longer available (Graven 2000). The infant is thus exposed to a greater number of higher frequency sounds after birth (Hall, 2000ii; Hendricks-Muñoz & Prendergast, 2007; Querleu, Lefebvre, Titran, Renard, Morillion & Crepin, 1984).

Full-term newborns have the ability to gradually adapt to the extra-uterine world and the abundant environmental noise to which they are exposed in the nursery. However, prematurity interferes with this process. The neonate is unprepared for life outside the womb and may lack the autonomic and functional maturity to deal with excessive stimuli (Bremmer, Byers & Kiehl, 2003; D'Agostino & Clifford, 1998; Reid & Freer, 2000; Singh & Deorari, 2003). This unpreparedness is due to the premature interruption of the development of the organisational stage of the central nervous system (CNS), which undergoes a critical period of growth from 5 months of gestation to 1 year of age (Blackburn, 1998). The ability of the preterm infant's CNS to capture and process environmental stimuli is ineffective. The premature infant's sensory system could become saturated and possibly over-stimulated by stimuli in a NICU (Aita & Goulet, 2003; Bremmer et al., 2003; Goldberg-Hamblin, Singer, Singer & Denney, 2007). Therefore noise in the NICU can have a disorganizing influence on the neurologically immature neonate.

2.3 NOISE AND THE EFFECTS ON THE INFANT IN THE NICU

Noise is defined as unwanted sound (Goines & Hagler, 2007) and has been “*documented as a noxious stimulus with deleterious physiological effects in the premature infant*” (Bremmer et al., 2003, p.448). The effects of noise on the cardiovascular and respiratory systems have been widely researched in both full- and preterm infants (Segall, 1972; Steinschneider, Lipton & Richmond, 1966 in Morris et al., 2000; Vranekovic, Hock, Isaacs & Cordero, 1974; Wharrad & Davis, 1997). These effects include decreased oxygen saturation levels, apnea, accelerations in heart rate and changes in the behavioural state of the preterm infant, specifically in sleep/wake cycles (Barreto, Morris, Philbin, Gray & Lasky, 2006; Bremmer et al., 2003; Morris et al., 2000). The effects have been most pronounced in the smallest and sickest preterm infants (Long, Lucey & Philip, 1980) as they are less able to handle surrounding stimuli (Gardner & Goldson, 2002).

Long et al. (1980) recorded tracings from preterm infant’s heart rates, respiratory rates, oxygen saturations and intracranial pressures during the routine NICU schedule. They demonstrated that hypoxia, increases in heart and respiratory rates and intracranial pressures occurred in infants in conjunction with sudden loud noise of around 80dBA. Periods of hypoxia created by environmental NICU stimuli with subsequent increase in intracranial pressure in the neonate may be associated with intracranial haemorrhage (Allen, 1995; Donn & Philip, 1978).

In another study, Zahr and Balian (1995) documented the effects of routine nursing procedures and loud noise events on the physiological and behavioural responses of preterm neonates in the NICU. They found that loud noise and nursing interventions had an immediate effect on decreasing oxygen saturation and increasing infant heart rates. They reported that 78% of premature infants changed their behavioural state in response to noise and nursing interventions.

Loud noises have also been found to be responsible for changes in sleep patterns of the premature infant (Allen, 1995; D’Agostino & Clifford, 1998; Hall, Ballweg & Howell, 1996). Tucker-Catlett and Holditch-Davis (1990) found that during a 2-hour observation

of five premature infants, 27 noise-induced changes occurred in the sleep/wake cycle. Moreover noise contributed to physiologic distress in infants. Due to these physiologic effects, the ill infant who often experiences environmental stress in the NICU, will have fewer calories available for growth and healing.

Allen, Donohue and Porter (2002) reported that hearing impairment occurs in approximately 1% to 10% of infants in the NICU. Preterm neonates have 5 times greater risk for the development of hearing loss compared to full-term babies (Singh & Deorari, 2003). The reason is that the hearing organ is still developing after birth in premature infants. Thus there is potential for the preterm neonate to develop a noise induced sensorineural hearing loss as a result of exposure to the intense NICU sounds (American Academy of Pediatrics, 1997; Blackburn, 1998; Passchier-Vermeer, 2000). A hearing loss developed as a result of noise exposure is usually in the mild to moderate range (25-55dB) (D'Agostino & Clifford, 1998). However, it is unclear whether hearing losses observed in preterm infants are solely the result of the effects of NICU noise exposure. The use of ototoxic drugs in the treatment of premature infants, for example aminoglycosides or loop diuretics, may increase the risk of the development of an ototoxic hearing loss in addition to the noise-induced hearing loss (American Academy of Pediatrics, 1997; Kent et al., 2002).

According to Philbin and Klaas (2000), the human voice is the most preferred sound to newborn infants. The use of music with preterm infants has not been well studied even though music has been shown to soothe full-term babies (Beal, 2007; Gardner & Goldson, 2002). Singh and Deorari (2003) reported that some studies have shown that soft and soothing music enhances physiologic stability and improves weight gain in individual premature infants. However, preterm infants may be unable to tolerate any additional sound and become exhausted by stimuli such as music because they are less able to habituate to sound compared to full term infants (Philbin, 2000).

Noise exposure in the NICU may also affect the auditory perceptual development of the preterm infant, because of the underdeveloped nature of the neonate's sensory systems

(Passchier-Vermeer, 2000). Research investigating the possible links between issues of prematurity and problems of children at school age is scarce. However, there is a relatively high occurrence of attention-related difficulties and information processing disorders once the preterm infants have reached pre- and school-going ages (Bremmer et al., 2003; McCormick, 1989) as well as speech delays, language-related problems and learning difficulties (Benini et al., 1996; Graven, 2000; Weisglas-Kuperus et al., 1993).

Premature infants are also at a significant risk for cognitive, behavioural, social and linguistic disturbances as well as visual and auditory deficits (Avery & Glass, 1989; Becker, Grunwald, Moorman & Stuhr, 1991; De Paul & Chambers, 1995; Ellison, 1984). Young (1996, p.2) states that the above-mentioned difficulties and deficits that the preterm infant exhibits are a result of the “*stressful nature*” of the NICU environment.

2.4 NOISE SOURCES IN THE NICU

The sounds generated in the NICU come from a variety of sources and comprise a wide frequency range although the noise is generally low frequency (Northern & Downs, 2002). Some sounds are continuous, anticipated and intense noises, such as apnea monitors, while others are episodic and unanticipated such as alarms, conversation and closing/opening of incubator portholes (Benini et al., 1996; D'Agostino & Clifford, 1998; Morris et al., 2000). The noise produced in the NICU is dependent on the ambient sounds, on the types of incubators and support equipment used, the number of infants and caregivers, on the infant's own behaviour as well as the activities of staff members (Byers et al., 2006; Gardner & Goldson, 2002; Gray et al., 1998; Jonckheer, Robert, Aubry & de Brouwer, 2004; Levy, Woolston & Browne, 2003).

Graven (2000) reports that in many NICUs, the belief is that high-technology intensive care is unavoidably noisy. Research studies have revealed that NICU sound levels vary between 50 to 75dBA with peaks of 105dBA and frequent, prolonged sounds in the 70 to 80dBA range (Benini et al., 1996; Blackburn, 1998; Busch-Vishniac, West, Barnhill, Hunter, Orellana & Chivukula, 2005; Elander & Hellström, 1995; Gray et al., 1998; Hoehn et al., 2000; Jonckheer et al., 2004; Kent et al., 2002; Krueger, Wall, Parker &

Nealis, 2005; Morris et al., 2000; Nzama et al., 1995; Robertson et al., 1998; Strauch et al., 1993). These sound levels exceed those encountered in the home environment as well as in a newborn nursery. Anagnostakis, Petmezakis, Messaritakis and Matsaniotis (1980) found that noise levels in a NICU were 6-8dBA higher than in a nursery. However, they may be as much as 20dB higher in some NICUs (Northern & Downs, 2002). In other words, the NICU noise levels can be 2 to 6 times more intensive than those in normal newborn nurseries. In terms of specific procedures that produce high levels of noise, the highest levels of noise recorded correspond to the time of admission of a neonate to the NICU (Anagnostakis et al., 1980; DePaul & Chambers, 1995).

Philbin and Gray (2002) measured the noise levels in a single, empty NICU before and after a staff education programme regarding the effects of NICU noise and a third time after a minor renovation to the physical space in the NICU. They found that even in an empty NICU, the noise levels varied between 51 and 68 dBA. This highlights that the NICU, even when empty, was never quiet.

The NICU has a multitude of sound sources. Numerous studies have examined these noise sources. Chang, Lin and Lin (2001) conducted a study in which peak noises were recorded during a 48 hour observation period in the NICU. They found that about 90% of loud noises were related to personnel activities such as opening or closing incubator ports and conversation. Machines have also been found to contribute to the NICU noise but to a lesser degree than staff activity (Benini et al., 1996; Busch-Vishniac et al., 2005; Elander & Hellström, 1995; Graven, 2000; Kent et al., 2002; Nzama et al., 1995; Zahr & Balian, 1995). The most vulnerable infants seem to be exposed to the most noise due to the equipment and critical care needed to keep them alive and stable (Levy et al., 2003).

Gardner and Goldson, (2002) tabulated the following actual sound levels for different activities in the NICU based on published studies (Table 2.1). These levels have been confirmed in numerous studies over the decades (Anagnostakis et al., 1980; Bremmer et al., 2003; Nzama et al., 1995).

Table 2.1: *Noise levels in the NICU* (Gardner & Goldson, 2002, p.249)

<u>Level (dBA)</u>	<u>NICU</u>
+44	Normal nursery
48-69	Humidifiers and nebulizers
50-60	Normal speaking voice
50-73.5 *	Incubator motor noise
53	Median noise level on conventional ventilator
55-88	Bradycardia alarm
58-85	Noise in NICU (talking, equipment alarms, telephones, radio)
59	Median noise level on high frequency oscillator
59-71*	Using hood of incubator as writing surface
65-80 *	Life support equipment (ventilator; IV pumps)
66-76	Sink on/off
67-72*	Incubator alarm
80	Tapping incubator with fingers
81-83	Crying of newborns
84-108	Placing a plastic bottle of formula on top of incubator
96-117 *	Placing a glass bottle of formula on top of incubator
70-116 *	Closing one or both cabinet doors under the incubator
80-124 *	Closing one or both portholes
120	Dropping the head of the mattress (correlates with threshold of pain)
130-140 *	Banging incubator to stimulate apneic premature infant

* Measured from inside the incubator

Most infants in the NICU are constantly exposed to the above levels of noise for 24 hours a day with no recovery time for weeks or even months. This is because it has been found that there is no difference in the noise levels between the day and night (Anagnostakis et al., 1980; DePaul & Chambers, 1995; Gardner & Goldson, 2002; Nzama et al., 1995; Philbin, Robertson & Hall, 1999; Strauch et al., 1993).

It is believed that the “*stress associated with the over-stimulation of immature neurological system in the NICU utilizes energy resources that would otherwise be used by the preterm infant to maintain homeostasis and promote growth*” (Aita & Goulet, 2003, p.111). This wasted use of vital energy by the premature neonate further highlights the necessity for the development and maintenance of standards and recommendations regarding noise levels in a NICU.

2.5 MONITORING NICU NOISE LEVELS AND NOISE ABATEMENT

The Occupational Health and Safety Act 85 of 1993 (as amended, 2003) recommends that adults exposed to occupational noise at the workplace should not work for more than 8 hours in exposure to 90dBA, 4 hours to 95dBA, 2 hours to 100dBA, with no exposure permitted to continuous noise above 115dBA or impulse noise greater than 140dBA. However, no standards have been established for neonates, but much emphasis has been placed on monitoring sound levels in the NICUs of both the preterm and term infants in order to not exceed recommended limits of sound exposure (Graven, 2000).

Since 1974 the American Academy of Pediatrics has recommended that sound levels for neonates should not exceed 45-50dBA (American Academy of Pediatrics, 1997; Buckland, Austin, Jackson & Inder, 2003; Graven, 2000). More recently established American and British standards state that average noise levels in NICU incubators should not exceed 60dBA (Levy et al., 2003). However, as shown earlier, numerous studies have shown that levels measured in the NICU exceed these recommendations (Benini et al., 1996; Blackburn, 1998; Elander & Hellström, 1995; Gray et al., 1998; Hoehn et al., 2000; Kent et al., 2002; Morris et al., 2000; Nzama et al., 1995; Robertson et al., 1998; Strauch et al., 1993) therefore highlighting the need for noise abatement in the NICU.

2.6 WAYS IN WHICH TO REDUCE NOISE LEVELS IN THE NICU

Several studies have investigated techniques for noise reduction in the NICU (Elander & Hellström, 1995; Gray et al., 1998; Johnson & Thornhill, 2006; Long et al., 1980; Robertson, Vos & Cooper-Peel, 1999). According to Philbin (2000), those programs that combined staff education about noise with the intention of reducing staff noise levels, have had temporary or limited success.

Long et al. (1980) used a self-correcting approach in which staff had to identify noise sources in the NICU. Once all noisy equipment was repaired, the only remaining noise sources were found to be the nursing staff themselves. Their study revealed that there was a lowering of the noise levels measured after the NICU staff modified their behaviour, although this was unsustainable without regular reinforcement. The researchers did not

consider building acoustics or NICU design, which have been found to influence the postnatal development of the preterm infant (Fifth Consensus Conference on Newborn ICU Design, 2002).

Elander and Hellström (1995) also examined whether providing educational information for nursing staff about noise pollution would lead to decreased noise levels in the intensive care unit for full-term infants. They implemented an intervention program, which consisted of 3 sections: (1) presentation of a video-tape of a post-operative infant, (2) presentation of decibel values of daily NICU activities, and (3) discussion of the problem. They found that following the intervention program, conversation by the nurses around the infants decreased from 62% to 14%. The findings of the study compare with those of Robertson et al. (1999), who also examined noise reduction strategies in the NICU.

Studies have also attempted to investigate whether implementing a 'quiet hour' protocol during certain times per day would reduce noise levels in a NICU. The concept of a 'quiet hour' protocol was developed in the original study by Strauch et al. (1993). They implemented a 'quiet hour' protocol involving noise reduction strategies implemented for the last hour of each shift. They found a significant decrease in noise during quiet hour (up to 10dB reduction) and infants spent more time in light or deep sleep during quiet hour periods. The reduced noise levels had a positive effect on infant state. However, the study did not address the noise levels occurring during other times of the day.

A follow-up study based on the one by Strauch et al. (1993) was conducted by Gray et al. (1998). They implemented a 'quiet hour' protocol for 2 hours during each eight-hour shift (morning, evening and night), involving light and noise reduction as well as optimal positioning strategies. A comparison of sound levels in the NICU measured during quiet and non-quiet times revealed a significant reduction in both variables, although sound levels decreased by a smaller percentage than light levels. This is probably due to the fact that it may have been difficult to maintain lower sound levels during all shifts because of

visiting hours and the unavoidable activity of a busy NICU, the use of life-support systems and staff conversation.

Studies by Saunders (1995) and Zahr and de Traversay (1995) illustrate that noise management in the NICU can be accomplished without directly manipulating the actual environment, including adjusting the machinery/equipment or attempting to change staff behaviour. Saunders (1995) found that covering the preterm infant's incubator with a blanket significantly reduced the noise level within the closed incubator, while Zahr and de Traversay (1995) found that when preterm infants wore mini earmuffs, the infants had significantly higher levels of oxygen saturation and fewer fluctuations of these levels. They also spent more time in quiet sleep states and were able to maintain more stable physiologic measures. However, it is unclear if earmuffs are in fact comfortable for the preterm infant to wear for long periods of time and whether they actually protect them from the noise produced from the incubator, respirator and other machinery in the NICU.

According to Buckland et al. (2003), commercially available hearing protection for neonates in the NICU produces a reduction of sound by only 7dB, which is insufficient for the level of noise exposure that has been documented in NICUs (Gardner & Goldson, 2002). Although ear protection for neonates has been shown to reduce behavioural and physiologic effects to noise, they will attenuate important sounds around the neonate, such as parental voice, which may hinder infant-parent attachment (Graven, 2000).

Apart from managing noise sources to create an environment in which the preterm infant can grow and thrive, the actual design of a NICU should also be controlled. The NICU itself should be designed to simulate the womb's ecology so to ensure maximum comfort for the preterm infants (Harris, Shepley, White, Kolberg & Harrell, 2006; Singh & Deorari, 2003). To that end, standards exist for reducing noise and its effect in NICU design. In South Africa, health establishments should comply with the SABS 0218, Part 1 - 1999 standard ('Acoustical properties of buildings Part 1: Grading criteria for the airborne sound insulation properties of buildings').

According to the Fifth Consensus Conference on Newborn ICU Design (2002), the NICU should be an environment that is acoustically friendly to the neonate. Consideration should be given to floor surfaces and ceiling finishes, which should respectively include resilient sheet flooring or carpeting as well as acoustic tiles, which have been found to reduce noise and reverberation within the NICU (Berens & Weigle, 1996). However, it must be noted that some background noise is generated in the hospital building itself, including communications (such as intercom systems), ventilation, plumbing, heating and air conditioning systems and equipment (such as computing/printing systems) (Fifth Consensus Conference on Newborn ICU Design, 2002).

2.7 SITUATION IN SOUTH AFRICAN NICUS

As a developing country, many state hospitals in South Africa have potentially fewer resources available to comply with acceptable standards of practice, including lack of or insufficient equipment, financial constraints and inability to recruit or retain nursing staff (Associate Prof. S. Clow, personal communication, April, 2005; Dr. M.E. Bester, personal communication, April, 2005). Acquired Immune Deficiency Syndrome (AIDS), population growth rate, increased urbanisation and poverty may all result in increases in the number of preterm infants in need of specialised services at South African hospitals. Although there are known staff shortages and lack of equipment, it has been found that in state hospital NICUs, the standards of care are generally good (Paediatric Neonatology Workgroup, 2003).

To date, there appear to be very few published studies on noise levels in NICUs in South African hospitals, such as the study conducted by Nzama et al., 1995. Their study was conducted at a NICU in a private clinic in Gauteng. The researchers identified noise sources and measured the noise levels in the NICU in order to provide guidelines for reducing or preventing noise in NICUs. They found that the noise sources can be divided into environmental, equipment-related, personnel and patient-related. Overall, the sound levels measured ranged from 64-66dBA, which is above the recommended levels for a NICU (American Academy of Pediatrics, 1997; Buckland et al., 2003; Graven, 2000; Levy et al., 2003). The researchers did not consider NICU building acoustics.

The above-mentioned South African study and the research conducted in this area in other countries highlights the intensity of the noise levels to which the neonates are being exposed and the need for NICU noise reduction. NICU noise abatement is a vital part of optimising preterm newborn patient care to improve the neonate's quality of life and may contribute to the preterm infant's physiologic stability and thus enhance growth and health in the neonate (Benini et al., 1996; Graven, 2000).

Further research regarding the noise levels in South African NICUs is essential. Bearing in mind the negative effects of noise on the preterm neonate and the excessive levels of noise in the NICU measured in some of the previous research, this study will attempt to conduct a detailed noise assessment in a NICU of a state hospital in the Cape Metropole as well as document infant responses to these levels in one state hospital in the Cape Metropole. This research is expected to provide an index of the existing noise levels and sources as well as the potential physiological responses of the infants to the noises. The results are expected to give guidelines to whether stricter noise management is required.

3. METHODOLOGY

The following section presents the aims, research design and subject selection criteria and description used in this study. In addition, the methods and procedures of data collection and methods of analysis are described.

3.1 RESEARCH AIMS

The main aim of this study was to investigate the noise levels and their potential effects on infants in a state hospital NICU in the Cape Metropole.

More specifically, this study aimed to:

1. Measure the noise levels in the general environment of the neonate in a NICU.
2. Identify the sources of noise in the NICU.
3. Record the physiological responses of the neonates in the NICU with regards to: heart rates, respiratory rates, blood pressure and oxygen saturation levels.
4. Investigate potential relationships between noise and infants' physiological responses.
5. Determine whether the noise levels in the NICU was a result of direct noise or reverberant noise from NICU room reinforcements
6. Feedback the results of the study to the nursing staff working in the NICU that was investigated and invite them to give suggestions for NICU noise abatement strategies.

3.2 RESEARCH DESIGN

This study utilised a non-experimental descriptive research design (Fouché & de Vos, 1998). It involved a measurement, analysis and detailed description of the noise levels and events in a NICU as well as recordings and relationship of the responses of the infants to the levels of noise in the NICU.

3.3 SUBJECTS

3.3.1 Subject selection procedure and sampling

3.3.1.1 *Hospital:*

The study was conducted at the Tygerberg Academic Hospital, which is a large state hospital in the Cape Metropole. It has a large and active NICU of approximately 2 rooms, in which only open incubators are used.

3.3.1.2 *Subjects:*

3.3.1.2.1 Inclusion criteria

1. Both sedated and non-sedated infants were included in the study due to the small potential sample size based on the maximum number of incubators in the NICU at one time (a maximum of 4 incubators per room).
2. Infants without a diagnostic medical history of: severe asphyxia, meningitis, congenital brain abnormalities and hearing loss. These would have an effect on their physiological responses (Cone-Wesson et al., 2000; Prof. G.F. Kirsten, personal communication, June 2006).
3. All infants had to pass Automated Auditory Brainstem Response (AABR) and Oto-Acoustic Emissions (OAE) screening. This was done to ensure that their hearing was within normal limits and they were able to hear the noises in the NICU. This inclusion testing was only carried out post-data collection, because the tests could not be conducted, while the subjects were ventilated as the sound of the ventilation interfered with the test results. Additionally, owing to neural immaturity, infants younger than 34 weeks gestational age could not be tested and the researcher had to wait till they were age appropriate before hearing screening could commence (Hall, 2000i).

3.3.1.2.2 Subject Selection Procedure

After receiving permission to conduct the study from the Research Committee at the Stellenbosch University Faculty of Health Sciences and the Medical Superintendent of the state hospital (see Appendices A & B), the researcher approached the parents of the infants residing in the NICU and informed them of the nature and purpose of the research and the precautions that were taken to ensure neonatal safety. The researcher made sure

they understood what the study entailed and allowed them to make an informed decision regarding participation. Each parent provided informed written consent for participation before their infant was included in the study. There were a total of eight infants in the two rooms. One mother absconded from visiting her baby, so permission was not obtained. Another parent declined participation. Thus the final sample consisted of 6 infants.

3.3.1.2.3 Description of subjects

The final sample consisted of 6 neonates whose parents gave written consent (see table 3.1 below). They were all neonatal inpatients in the NICU and all underwent and passed the AABR and OAE screeners. If there had been infants that did not pass the screener(s), they would have been referred for further audiological follow-up and would not have been included in the final sample of the study.

Table 3.1: Subject description

	<u>Gestational age</u>	<u>Birth weight</u>	<u>Presentation</u>
Subject 1	Term baby	2900g	<ul style="list-style-type: none"> • Respiratory distress syndrome • Antenatal hypoxia • Ventilated
Subject 2	Term baby	3050g	<ul style="list-style-type: none"> • Congenital in cyst neck (left) with upper airway obstruction → pre- and post-excision of cyst • Ventilated
Subject 3	30 weeks (corrected 34 weeks)	940g	<ul style="list-style-type: none"> • Exceptionally low birth weight • Premature • Apnoea • Ventilated
Subject 4	30 weeks (corrected 34 weeks)	1200g	<ul style="list-style-type: none"> • Very low birth weight • Premature • Subtotal colostomy (2-stage surgical correction) • Oscillator
Subject 5	33 weeks	1600g	<ul style="list-style-type: none"> • Low birth weight • Premature • Neonatal encephalopathy • Sentinel event • CPAP (Continuous Positive Airway Pressure)
Subject 6	39 weeks	2160g	<ul style="list-style-type: none"> • Fetal distress • Respiratory distress syndrome • Large aorta pulmonary window • Subtotal colostomy (2-stage surgical correction) • Ventilated

3.4 INSTRUMENTATION AND MATERIALS

3.4.1 *Sound level meter (SLM):* A battery-operated calibrated NTI Acoustilyzer AL1 SLM with an omni-directional pre-polarised free-field condenser microphone was used for the sound level- and reverberation time measurements in the NICU. The measurement range was 60-140dB. The meter was set to record A-weighted slow response L_{Aeq} over a 12 hour period and SPL, MinL and MaxL every 30 seconds over the 12 hours. See glossary for definition of terms (Gray & Philbin, 2000; Robertson et al., 1998).

3.4.2 *Hearing screening equipment:* All hearing screening equipment was small and portable, which made testing unproblematic to carry out in different localities. The Madsen *AccuScreen* Transient-Evoked Oto-Acoustic Emissions (OAE) screener and Natus *Algo3i* Newborn Automated Auditory Brainstem Response (AABR) screener were used to determine the neonates' hearing status.

3.4.3 *Checklist of noise events:* A checklist (see Appendix D) was developed by the researcher, based on information from the literature regarding noise, the NICU and the preterm infant (Nzama et al., 1995; Chang et al., 2001) as well as on informal observation of the activities at the NICU. The researcher noted all 'noise events' and their sources in the NICU as they occurred during spot-check observations by the researcher while noise levels were being measured.

3.4.4 *Equipment used to measure and collect the physiological responses:* A central hub computer was linked to the monitors displaying the vital signs of each infant in the NICU. The information recorded for each infant was printed out using a laser printer at the end of each of the noise measurement periods.

3.4.5 *Equipment used to measure reverberation time:* A high quality loudspeaker attached to a CD player was used to produce and deliver the wideband "sh-h-h" noise into the empty room. The decay of the sound was measured and stored on the same SLM that was utilised in the noise level measurements.

3.5 ETHICAL CONSIDERATIONS

3.5.1 *Permission to conduct research and informed consent*

Ethical approval was granted by the state hospital's Department of Paediatrics Research Committee as well as the Research Committee at the Stellenbosch University Faculty of Health Sciences (see Appendix A).

Permission to conduct the research study was obtained from the Medical Superintendent at the state hospital (see Appendix B). Signed consent was also obtained from the parents of the neonates occupying the open incubators in the NICU at the hospital (See Appendix C). Confidentiality and anonymity was ensured. The researcher informed them that they were free to withdraw consent for their infants to participate in the study at any time and that they were not responsible for any costs related to the study. The risks of participation were outlined. They were also informed that although they would not benefit directly from the study, the information obtained would be used to improve the monitoring of the NICU noise levels and to recommend changes that could be made in the NICU to maintain lower noise levels.

3.5.2 *Sterilization of noise measuring equipment*

In order to conduct research in a NICU, it was vital that all instruments and equipment were completely sterilised to minimise the risk of infection to the neonates (Gray & Philbin, 2000). The researcher cleaned the SLM microphone every morning with an alcohol swab before suspending it from the ceiling to minimise the risk of infection to the infants.

3.5.3 *Calibration of equipment*

Calibration of the noise level measuring and hearing screening equipment was valid and had been done in the past 6 months prior to commencement of the study by a South African National Accreditation System (SANAS) accredited laboratory. This guaranteed that the instruments were working according to the manufacturer's specifications. For both the noise level and reverberation measurements, the researcher consulted with the technical advisor to the study regarding correct set-up and management of the SLM and results obtained.

3.5.4 *Informing the nursing staff*

Prior to the start of the study, the Matron of the NICU was informed about the study and the rationale behind the study in order to gain the Matron's support for the study, which was conducted in her unit. Subsequently, the nursing staff were orally informed by the researcher that the study was being conducted, because the hospital was concerned about the levels of noise in the NICU. They were also informed that the SLM was not a tape-recorder and therefore only the level of sound was recorded, not voices and conversations (Gray & Philbin, 2000).

3.5.5 *Data records*

All information obtained from the printouts of the physiological data regarding the neonates, and the information gathered during the spot-check observations by the researcher was coded by number and remained completely confidential. All data collected from the feedback to the nursing staff remained confidential. No names or personal information appear in any publication of this study. All records and data from the study were stored in a lever-arch file in a locked drawer at the office of the researcher.

3.6 DATA COLLECTION PROCEDURE

The procedure for main data collection was based on the triangulation method (Denzin, 1989 in Janesick, 1998) (See Table 3.2):

Table 3.2: *Data collection procedure*

• Hearing screening of the neonates who parents' consented to their participation
• Noise level measurement data collected from both rooms in the NICU using the central site method (Robertson et al., 1998)
• Observations of the NICU by the researcher to identify the possible noise sources in each room and compile a checklist of these sources
• Documenting the neonate's physiological responses to noise levels in the NICU
• Measurements of NICU reverberation time to determine whether the NICU noise levels are a result of direct noise or reverberant noise from room reinforcements
• Feedback of study to and from nursing staff working in the NICU

3.6.1 *Hearing Testing procedure*

Screening the hearing of the infants in the NICU was difficult due to the noise of the ventilators and general NICU noise, which interfered with the testing. As a result both OAE and AABR screening only occurred once the infants had been moved to the Kangaroo-Care ward or had been transferred to other hospitals in the Cape Metropole. The procedure of the OAE and AABR tests were as follows (Olusanya et al., 2007):

- **OAE screening**

OAE screening is a measurement of outer hair cell cochlear integrity (Hall, 2000i). It was done by placing a soft probe of the machine into the infant's ear (one ear at a time). The probe sent a clicking stimulus into the ear. The result read either "pass" or "refer" (fail). Passing the test suggested normal cochlea and middle ear functioning.

- **AABR screening test**

AABR screening was performed in order to negate auditory neuropathy (Olusanya & Oloko, 2006). This was done by placing stick-on electrodes onto the centre of the infant's forehead, the back of the neck and onto the back of the infant's shoulder. Stick-on cup earphones were placed on the ears. Both ears were tested at the same time. A single, low level click stimulus was sent into the ear at 35dB nHL to elicit the ABR. A computerised detection algorithm was used to decide whether a response was present by comparing incoming data to a template of a normal waveform stored in memory. The results of this comparison yielded a decision of either "pass" or "refer" (fail), depending on whether a response was detected (Natus Medical Inc, 2004). Passing the test suggested hearing within normal limits.

3.6.2 *Noise levels measurements*

A Type 1 SLM was used to measure the noise levels. All measurements were made according to the relevant South African National Standard (SANS): 10083 (2004). The noise levels in the NICU rooms were expressed in dBA. According to SANS: 10103 (2003), a noise level meter should be set to the 'A' weighted filter network for use in noise measurements in noise surveys.

The collection of noise measurements in both NICU rooms was done using the central site procedure (Robertson et al., 1998). Noise level measurements were taken during two separate 12-hour periods per room, which assisted in verifying the reliability of the measurements (Terre Blanche & Kelly, 1999). In each room the measurements were taken from 08h00 to 20h00 during 2 consecutive weekdays. The researcher “reset” the SLM data and saved the newly-recorded noise level data approximately every 4 hours during each of the 12-hour measurement periods to ensure that no data was lost in the case of a power failure. No noise level measurements were taken during the night shift, as it has been reported that little difference was found between sound levels during the day and night shifts (Nzama et al., 1995; Robertson et al., 1998).

The microphone of the SLM was suspended from the middle of the ceiling in each of the rooms, with the microphone at a height of 2m to avoid interfering with staff activities in the NICU (Robertson et al., 1998; SANS: 10083, 2004). This enabled the measurement of the noise levels that the neonates were exposed to in the NICU room. This method of collecting noise level data has been found to be the most accurate in reflecting the noise exposure in an open NICU by Robertson et al. (1998), who compared three methods of noise level measurements.

Prior to the commencement of the noise measurements, the microphone of the SLM was securely fastened to the ceiling and the extension cord attached to it was secured to the wall of the unit by duct tape to ensure that it would not become loose and fall. Both the microphone and cord were left in this position for one week prior to beginning the measurements. This was hoped to prevent the nursing staff from knowing when the measurements were taking place and also allowed the staff time to get used to having the SLM microphone suspended in the unit. It has been found in previous studies in the NICU that the nursing staff altered their behaviour when they knew what the studies entailed (Prof G.F. Kirsten, personal communication, March 2006).

Each morning prior to beginning the measurements, the researcher set-up the SLM and connected it to the microphone. Every effort was made to avoid interference with the daily activities in the NICU when the equipment was set-up.

On completion of each measurement, the researcher removed the microphone, SLM and recording equipment from the room. The extension cord of the SLM was left suspended until noise measurements had been completed for that room. All noise measurement data was downloaded from the SLM to the researcher's computer each night after measurements, using Microsoft® Notepad (Version 5.1) then copying the data to a Microsoft Office Excel Worksheet for analysis.

3.6.3 Observation and documentation of noise events

The researcher was not present for the entire noise measurement period, as her presence in the NICU might have influenced the behaviour of the NICU nursing staff. However, sporadic spot-check observations during the noise measurement periods (08h00-12h00;12h00-16h00;16h00-20h00) were carried out by the researcher, to observe everyday NICU activity and noise events as well as scheduled events, such as nursing care procedures, ward rounds and staff handovers. The noise events were noted and the frequency of occurrence recorded on the checklist.

3.6.4 Documenting the neonate's response to noise levels in the NICU

The measurement of the infants' vital signs, namely blood pressure, oxygen saturation, heart rate and respiratory rates were downloaded and stored every 5 minutes on a central hub computer linked to the equipment monitoring each of the infants in the NICU. Printouts of these responses were made at the end of each of the four 12-hour noise measurement periods for each of the subjects by the researcher.

3.6.5 Measurements of NICU reverberation time

Reverberation time of an 'empty' NICU room was calculated in order to determine whether the noise levels in the NICU were a result of direct noise or reverberant noise

from NICU room reinforcements. The same SLM used in the noise level measurements was utilised.

The room geometry of the NICU rooms was recorded using a Leica Disto A2 Laser Distance Meter. The dimensions for the two NICU rooms observed in the study were the same: 7.6m x 6.3m x 2.8m. Using these values, a room further down the passage in the same ward, similar in geometry and design to the NICU rooms under investigation, was selected by the researcher and Medical Superintendent so that reverberation measurements could be made without disturbing the day-to-day activities and care in the NICU rooms.

Actual reverberation time in seconds of the ‘empty’ room was measured utilising sound decays. The following set-up was used (see Figure 3.1):

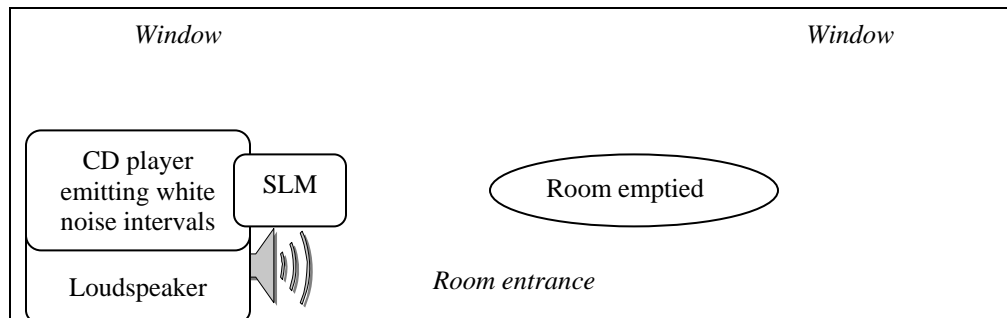


Figure 3.1: *Equipment arrangement used to measure the reverberation time of the room*

A loudspeaker attached to a CD player was aimed at the centre of the room. The CD was programmed to play a wideband “sh-h-h” noise (125 Hz to 4 kHz in the octave band) of more than 100dBA for 10 seconds. After the 10 second interval, the white noise ceased and the sound in the room decayed. The decay time was measured in seconds and stored on the SLM. These measurements were used to determine the actual reverberation time of the ‘empty’ room, similar to that of the NICU rooms. This procedure was repeated a total of three times (that is 3x 10 seconds) over a five minute period (Alton Everest, 2001; Mr. T. Mackenzie-Hoy, personal communication, March 2006).

3.6.6 *Feedback of the results to the staff*

Initially it was planned to have 2 fifteen-minute feedback meetings during working hours (morning and afternoon tea break) for the NICU staff and as well as one 1-hour long focus group discussion for the staff participants to comment on the study and to give suggestions on how to reduce the noise pollution in the NICU. However, once data collection had been completed, it was found that practically no time was available for the nursing staff to attend the feedback meetings and much less the hour focus group for feedback and discussion.

After four months of attempting to bring together the nursing staff for the focus group discussions, it was decided, based on the advice of the Unit Manager, that each of the nursing staff in the NICU, would receive a written summary report of the main points of the results (noise level measurements, checklist of the noise events, documentation of the neonate's responses to the noise levels in the NICU and measurements of NICU room reverberation time), which was drawn up by the researcher. The summary report included a description of the decibel values for various care activities in the NICU and gave everyday sound sources of the same decibel values. It also described the NICU noise levels and their potential effects. At the end of the summary report, the nursing staff were invited to give written suggestions on how to reduce the noise pollution in the NICU. Completing the form was voluntary. See Appendix E.

The nursing staff were given 10 days to read the summary report and complete the report. A total of nine out of ten forms distributed to the nursing staff were returned completed to the researcher. Eight of the nine respondents were actual nursing staff working daily in the NICU and the ninth respondent was a Neonatal Mentor at the hospital, with a PhD in Developmental Care.

3.7 RELIABILITY AND VALIDITY CONSIDERATIONS

3.7.1 *Data sources*

The data collection in this study was carried out based on the method of triangulation (Denzin, 1989 in Janesick, 1998). Triangulation is a process whereby one source of

information is checked against one or more other sources (DePoy & Gitlin, 1994). This allows the researcher to understand the phenomenon under investigation by approaching it from different angles, which will ensure that there is valid interpretation of the data (Terre Blanche & Kelly, 1999). This helps improve validity and reliability of the study when reporting the findings. Triangulation can involve using several kinds of methods or data, including quantitative and qualitative approaches. Data sources in this study included noise level measurements in each NICU room, printouts of the physiological responses of the neonates and documentation of the NICU noise sources.

3.7.1. Checklist of the noise events

i) Reliability: Observation and documentation of the checklist items was undertaken by a researcher, who is independent of the hospital under investigation. This neutrality enhanced the confirmability of the observations (Terre Blanche & Kelly, 1999). A research assistant was not used for the observations and documentation or to verify the occurrence of the noise events. The researcher felt that the noise events were quite clear cut, on-and-off type of events. As a result, there was little or no potential for discrepancy in noting the frequency of occurrence of the events.

ii) Content validity: The items on the checklist were compared with those found in published studies (Nzama et al., 1995; Chang et al., 2001). It was found that the checklist items documented similar events and that the checklist items accounted “*for all the elements of a variable or issue being investigated*” (Katzenellenbogen, Joubert & Abdool Karim, 1997, p.92).

3.7.1.2 Printouts of the neonate’s response to noise levels in the NICU

The equipment monitoring and storing the data for each infant were calibrated and were working according to the manufacturer’s specifications. The researcher consulted with the technical representative of the company who supplied the equipment to ensure this.

3.8 DATA ANALYSIS

3.8.1 *Noise level measurements*

All noise level data was downloaded using the manufacturer's computer software. It was later converted by the researcher to a Microsoft Office Excel Worksheet for analysis. The results of the measurements contained data relating to L_{Aeq} , mean hourly SPL, $MaxL_A$ and $MinL_A$ (see Glossary of Terms) for each measurement period. Percentile levels for SPL, $MaxL_A$ and $MinL_A$ were also calculated. Data "cleaning" was carried out wherein all insignificant outlying peaks and troughs in each measurement were excluded from the analysis so that they would not confound the results of the study (T. Mackenzie-Hoy, personal communication, November 2006).

3.8.2 *Checklist of noise events in the NICU*

Frequency distribution of the noise events allowed for the data to be organised in "*some sort of logical order*" (Howell, 1999, p.32). The data was analysed using frequency counts and percentages, since all the information was categorical data (Howell, 1999).

3.8.3 *Printouts of neonatal responses to NICU noise*

Only heart rate and respiratory rate were analysed, because these were the only consistent variables monitored in all of the consenting subjects. Oxygen saturation and blood pressure could only be measured for some of the subjects and it was felt that, due to the very small sample size (6 subjects), only those measures available for all infants would be analysed.

The data recorded by the computer hub was printed out using a laser printer at the end of each of the noise measurement periods in table format for each of the neonates under investigation. The researcher copied these tables onto a Microsoft Office Excel Worksheet, as this would make it compatible for analysis.

3.8.4 Statistical Analysis

All statistical analyses regarding the physiological responses of the neonates in this research study were performed using a computer-based statistical programme, *Statistica 7.0* (StatSoft Inc., 2004).

Repeated measures analysis of variance (ANOVA) test and Spearman's correlation coefficient was calculated to investigate interaction between the physiological responses of the neonates in the NICU and the rooms and days in and on which the measurement occurred in the NICU. ANOVA is "*a statistical technique for testing for differences in the means of several groups*" (Howell, 1999, p. 457). Repeated measures ANOVA is utilised when the subjects are measured repeatedly. Spearman's correlation is a non-parametric correlation, which is used as a measure of the relationship between variables, specifically ranked data (Howell, 1999, 154). In the case of the present study, the vital signs of the same infant subjects were measured for two separate 12-hour periods.

Correlations of heart- and respiratory rate with noise level

Correlations of heart- and respiratory rates with the noise levels were investigated per participant and as well as the correlations of the average heart- or respiratory rate of the participants with the noise levels in each room. This was performed in order to determine if and how the heart- and respiratory rate were influenced or not by the noise levels measured. The Shapiro-Wilk test for normality of data was initially used to find if the noise levels and the heart- and respiratory rates of the neonates were normally distributed (Conover, 1999). If these results yielded that the null hypothesis is rejected ($p < 0.05$) - that is, the noise levels and the heart- and respiratory rate data were not normally distributed - the Spearman correlation coefficient was performed to investigate the correlations between the heart rate and noise levels as well as the respiratory rate and the noise levels, for any of the participants in either room.

3.8.5 Reverberation measurements

In order to determine whether the noise levels in the NICU were a result of direct noise or reverberant noise from NICU room reinforcements, actual reverberation time

measurements were made by the researcher as well as estimated according Sabine's mathematical equation (Alton Everest, 2001).

The room volume was multiplied by 0.161 and then divided by the reverberation time values obtained during the actual reverberation time measurements for each pre-determined frequency (as determined below in Figure 3.2 by Sabine's equation (Alton Everest, 2001)) in order to calculate the total absorption values for each frequency.

$$A = \frac{(0.161V)}{RT(Hz)}$$

Key - **RT** is the reverberation time (per pre-determined frequency) ;
V is the volume of the enclosure (m³) ;
A is the total absorption within the enclosure (Sabine).

Figure 3.2: Sabine's equation to calculate reverberation time (Alton Everest, 2001)

The reverberation time was then entered into an equation measuring the SPL (dBA) of the average number of people in the NICU room at one time (as used in the calculations in Sabine's equation) talking at an average volume level. This value, together with the actual noise measurement values obtained in the noise measurements, assisted in determining whether the NICU noise levels were a result of direct or reverberant noise from NICU room reinforcements.

3.8.5 NICU nursing staff feedback

All written responses were counted, coded and grouped for trends and main ideas.

4. RESULTS AND DISCUSSION

The results will be described and discussed in accordance with the aims of the study. The actual noise levels and the observed sources of noise in the environment of the neonate in a NICU will be presented first. Next the physiological responses of the neonates with regards to heart rates and respiratory rates will be highlighted. Following this, an assessment of whether the noise levels in the NICU was a result of direct noise or reverberant noise from NICU room reinforcements will be given. Lastly, the findings from the NICU nursing staff feedback will be presented.

4.1 NOISE LEVELS IN THE NICU

In general, it is said that it is poor science to plot graphs with a suppressed zero. However, in the case of SPL measurements, 0dB indicates a value one million times less than, for example, 60dB. Since, decibels represent a logarithmic weighted value of SPL, which is measured as air pressure variation in N/m^2 (T. Mackenzie-Hoy, personal communication, November 2006). As a result, all graphs in the section that follows have suppressed zeroes and are plotted over approximately 25dBA range, which is roughly indicative of the loudness of the various noises measured in the NICU rooms.

LAeq and SPL measurements

The mean hourly SPL and the L_{Aeq} values obtained at the end of each “reset” period in each of the rooms over the two days of noise level measurement were similar and ranged from 62.3-66.7dBA (L_{Aeq}) to 61.0-66.0dBA (SPL). Table 4.1 depicts the value ranges in dBA for both L_{Aeq} and SPL per room per day.

Table 4.1: *Decibel (A) value ranges for LAeq and SPL per room per day*

<u>Room</u>	<u>Day</u>	<u>LAeq</u>	<u>SPL</u>
1	1	63.5-66.7 dBA	62.0-66.0 dBA
1	2	62.3-64.6 dBA	61.0-64.0 dBA
2	1	64.2-65.2 dBA	63.0-65.0 dBA
2	2	64.5-65.3 dBA	61.9-64.8 dBA

The recommended hourly L_{Aeq} for a NICU has been documented as being 50dBA (Philbin et al., 1999; Third Consensus Conference on Newborn ICU Design, 1996), while more recently established American and British standards state that average noise levels in NICU incubators should not exceed 60dBA (Levy et al., 2003). Either way, the results of this study indicate that the noise levels found far exceeded these values. (Note: Due to decibels being logarithmic in nature, a 3dB increase in SPL is in fact a doubling of noise level). Numerous published studies found similar NICU noise level results that exceeded these recommendations (Benini et al., 1996; Blackburn, 1998; Elander & Hellström, 1995; Gray et al., 1998; Hoehn et al., 2000; Kent et al., 2002; Morris et al., 2000; Robertson et al., 1998; Strauch et al., 1993), including Nzama et al.'s study (1995), conducted in a private clinic in Gauteng (South Africa), which measured sound levels that ranged from 64-66dBA. Perhaps the assumed differences between the public and private health sectors in South Africa are not that contrasting and perhaps the same problems regarding elevated noise levels in the NICUs are found across the health sectors in South Africa and abroad. Nevertheless, the elevated noise levels found in this study may have an effect on the hearing acuity of both the infants staying in the NICU and on the staff members working in the NICU.

Illustrated below are the L_{Aeq} values for the 12 hour measurement period and hourly SPL plotted per room per day (See figures 4.1-4.4 below).

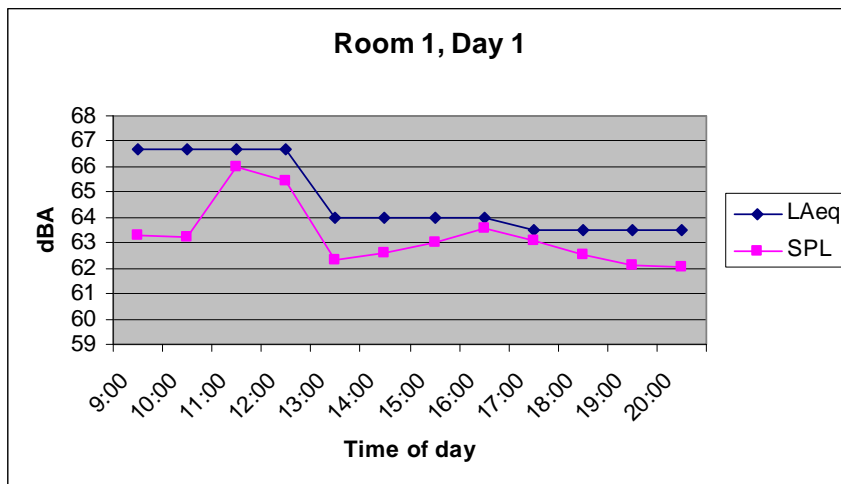


Figure 4.1: *Distribution of LAeq and hourly SPL in room 1 on day 1*

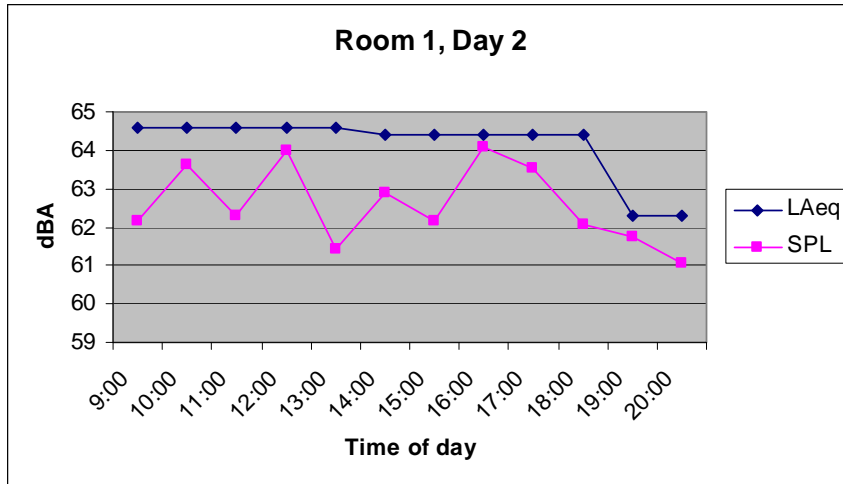


Figure 4.2: Distribution of LAeq and hourly SPL in room 1 on day 2

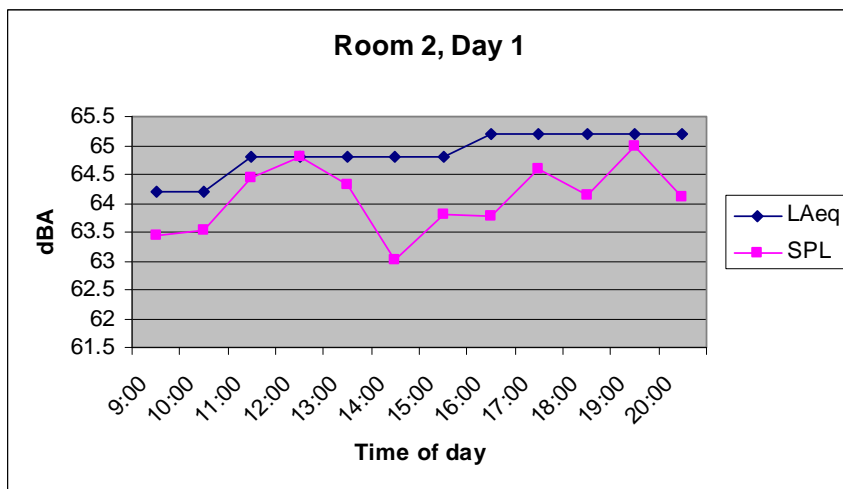


Figure 4.3: Distribution of LAeq and hourly SPL in room 2 on day 1

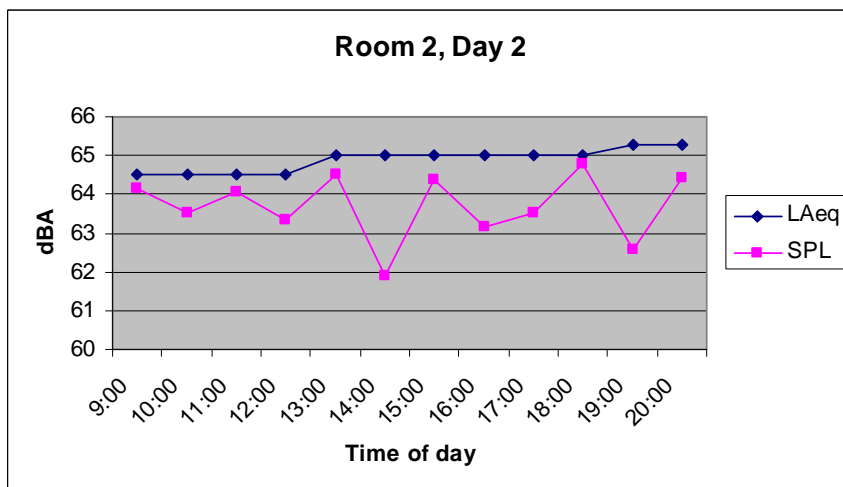


Figure 4.4: Distribution of LAeq and hourly SPL in room 2 on day 2

As can be seen (figures 4.1 and 4.3) the noise measurements appeared somewhat lower (around 63 dBA) during the morning of day 1 in both rooms than during most other times. It is possible that on day 1, knowing that noise levels were being measured and seeing the researcher present, NICU staff and parents may have initially altered their typical behaviours in both rooms. This phenomenon was similarly reported by Levy et al. (2003). It was also pointed out to the researcher during the present study by some of the Paediatricians working in the NICU. At the end of the noise measurement period on day 1 in the first NICU room, they reported that they were intentionally quieter in the morning when all the noise measuring equipment had been set up and the researcher was present. Yet, as the day went on and they became accustomed to the presence of the investigation equipment and the researcher, both the doctors and nursing staff reverted back to their natural behaviour.

L_{Aeq} patterns appear to be slightly different between room 1 and room 2. In room 1, L_{Aeq} values for both days tended to decline to a minimum of 63.5dBA (day 1) and 62.3dBA (day 2) as the 12-hour measurement progressed. As seen in Figure 4.1, this decline took place earlier on day 1 around the 9th hour compared with around the 11th hour on day 2. Conversely, the L_{Aeq} values in room 2 over both days appeared to steadily rise to a maximum of 65.2dBA (day 1) and 65.3dBA (day 2) by the end of the measurement periods.

From the graphs, it can be seen that the SPL value graphs over the four periods of measurement varied (61.04dBA to 65.97dBA) and it was difficult to determine patterns of similarity or difference. However, this variation of SPL values may have been due to the fact that most activities in the NICU rooms varied according to day, number of inpatients, staff and/or parents present and equipment used. The SPL graph for day 1 in room 1 appears to show a less erratic pattern than those from the other 3 periods of measurement. This, again, may be owing to the fact that the nursing staff altered their behaviour on the first day of measurement.

Rooms were generally much busier during the morning hours as various staff were constantly in and out of the rooms, including radiology, surgical rounds, regular ward rounds, care-giving and cleaning of the rooms. Over the lunch hour, fewer people were present in the rooms. A minimum, of 2 staff members were in the rooms at all times to monitor and care for the infants. The afternoons tended the quieter periods of the day leading up to staff change-over at 18h00.

It must be noted that all four graphs above (figures 4.1-4.4) do not have the same y-axis value range and so the noise levels obtained may appear to fluctuate more than if the graphs had utilised the same value range for the y-axis. However, the fluctuations of noise over time in both rooms on both days may be owing to the fact that ventilator and oscillator machinery, care-giving and nursing activities and difference in staff personalities varied between rooms and days on data collection.

Percentile Levels

Percentile levels (L_n) were analysed for SPL, MinL and MaxL for both rooms over both days (see figures 4.5-4.7 below). L_n documents the level of sound exceeded $n\%$ of the time during the measurement period. L_{10} , L_{50} and L_{90} were examined for SPL, MinL and MaxL. L_{10} is the level of sound exceeded for 10% of the measurement period, similarly L_{50} is for 50% of the time and L_{90} is for 90% of the time. According to Gray and Philbin (2000, p.S100), it would make sense that for $L_n(\text{SPL})$ and $L_n(\text{MaxL})$ the “higher the percentage, the quieter the sound”, while the opposite is true for $L_n(\text{MinL})$.

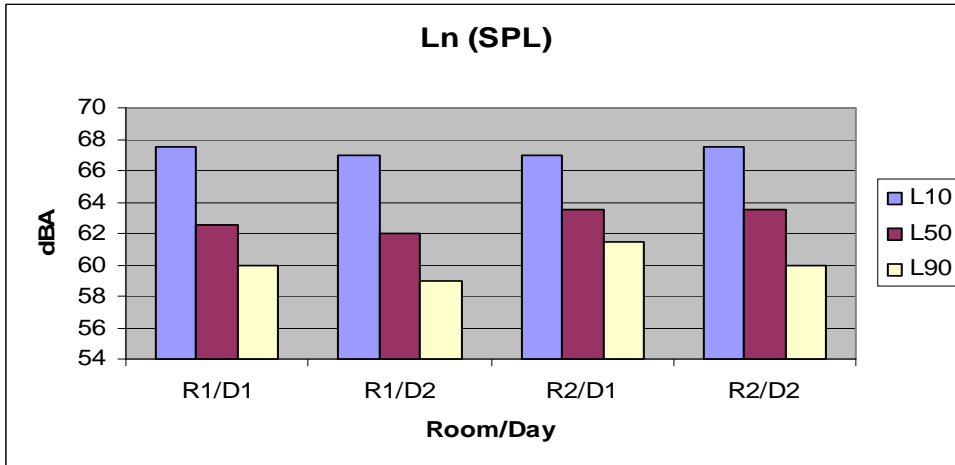


Figure 4.5: *Distribution of Ln for SPL*

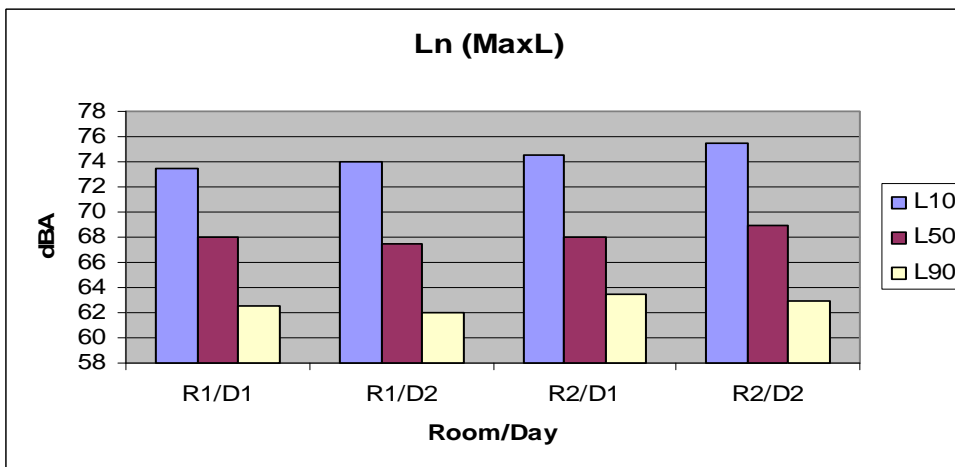


Figure 4.6: *Distribution of Ln for MaxL*

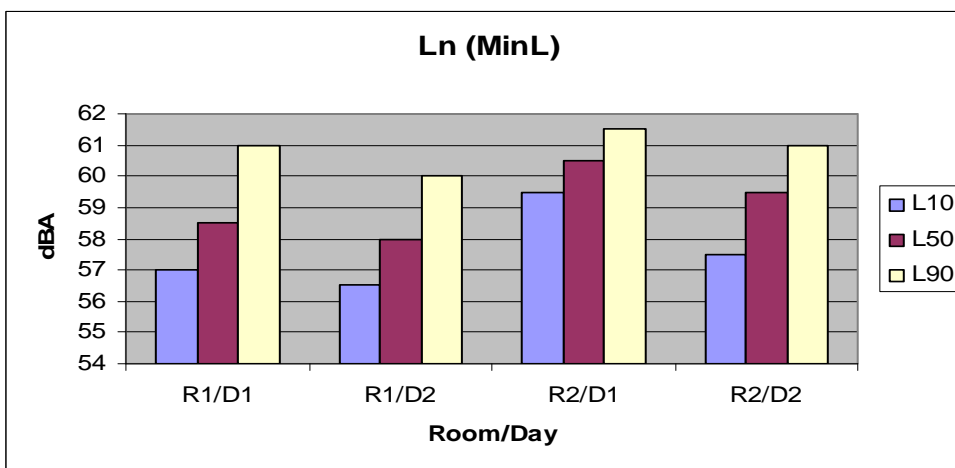


Figure 4.7: *Distribution of Ln for MinL*

In general, figures 4.5-4.7 illustrate that the percentile levels (L_n) for SPL, MaxL and MinL for both rooms over both days were slightly higher in room 2 than room 1 by between 1.0-1.5dBA (SPL), 0.5-2.0dBA (MaxL) and 1.0-3.0dBA (MinL). This may be owing to the fact that, by the time the measurements were taken in the second room, the NICU staff (paediatricians, nursing and cleaning staff) were perhaps used to the presence of the researcher in the NICU rooms and the measurements in room 2 were perhaps more of a true representation of the actual day-to-day noise levels in the NICU.

Figure 4.5 shows that on average, L_{10} (SPL) was 67dBA, which is indicative of the upper limit of fluctuating noise in the NICU. L_{90} (SPL) is approximately 60dBA and reflects the ambient noise level in the NICU rooms under investigation. The recommended hourly L_{10} (SPL) for a NICU is 55dBA, which means that sound levels should exceed 55dBA only 10% of the time (Philbin et al., 1999; Third Consensus Conference on Newborn ICU Design, 1996). Thus an averaged measured L_{10} (SPL) value in the NICU rooms of 67dBA is considerably more than recommended.

L_n (MaxL) correlate to bursts of noise of more than one second in duration, which may also rouse infants or cause a startle (Philbin et al., 1999). The values obtained in the study for L_n (MaxL) (see figure 4.6) were high. On average, L_{10} (MaxL) was measured to be about 74dBA (range: 73.5-75.5dBA), whilst the level of L_{90} (MaxL) was significantly lower at approximately 62.5dBA (range: 62.0-63.5dBA). The recommended hourly MaxL for a NICU is no more than 70 dBA, which means that the sound levels should not exceed 70dBA (Philbin et al., 1999). So in the current study, it was found the recommended 70dBA for MaxL was exceeded 10% of the measurement periods, while for the majority of the time (90%), MaxL was within the recommended limits.

It can be seen from figure 4.7 above that the L_{10} and L_{50} figures for MinL for room 2 on both days are slightly higher at 59.5dBA (L_{10}) and 60.5dBA (L_{50}) than the values obtained from measurements in room 1 on both days of 57.0dBA (L_{10}) and 58.5dBA (L_{50}). This may be due to the fact that subject 6 (from room 2) was placed on an oscillator ventilator during day 1 and was taken off mid-way through day 2. The noise of the

oscillator may have increased the minimum noise levels in room 2. According to the paediatricians who work in the NICU, the oscillators are older machines, which tend to produce more noise than the newer ventilators that are being used in the NICU. Their level of $L_{90}(\text{MinL})$ is about 60dBA, whilst the level of $L_{10}(\text{MinL})$ is marginally lower of approximately 60dBA.

The noise levels found in the present study exceeded all recommendations for a NICU. It is noted, though, that often high-technology intensive care is unavoidably noisy (Graven, 2000). However, most infants in the NICU are in-patients for extended periods of time and are thus exposed to these levels 24 hours a day with no recovery time. The literature states that sensorineural hearing impairment occurs in approximately 1% to 10% of infants in the NICU, which could be the result of noise exposure to the intense NICU sounds (Allen et al., 2002; American Academy of Pediatrics, 1997; Blackburn, 1998). By law, adults working in noise have to have a recovery period between shifts (the Occupational Health and Safety Act 85 of 1993 (as amended, 2003)).

In light of the above it is fair to assume that continuous exposure to noise of these levels, similar to the constant sound of a vacuum cleaner (American Academy of Pediatrics, 1997), during an infant's stay in the NICU is nevertheless significant. In practical terms the measured noise levels could possibly result in anywhere between 1 and 10 in 100 neonates acquiring a hearing as a result of their stay in the NICU (Allen et al., 2002). An attempt should be made to minimise or prevent auditory damage to these, already fragile and physiologically unstable, neonates.

In addition to the effect of noise on the neonate in the NICU, DePaul and Chambers (1995) highlighted the fact that the nursing and other staff as well as the parents of the neonates may also be affected by the levels of NICU noise found in the current study, such as the potential of developing a noise induced hearing loss and other responses to noise such as fatigue, impaired judgement, irritability and altered perceptions, which may make NICU staff more prone to errors in patient care.

Summary

The noise levels found in the present study exceeded all recommendations for NICUs which vary between the “older” 50dBA and more recently established American and British standards of no more than 60dBA (Levy et al., 2003; Philbin et al., 1999; Third Consensus Conference on Newborn ICU Design, 1996). Continuous exposure to these high noise levels during an infant’s stay in the NICU could be potentially harmful to the infants’ health stability and auditory system. In addition, the general wellbeing of the staff working in the NICU may be compromised (American Academy of Pediatrics, 1997; DePaul & Chambers, 1995).

4.2 SOURCES OF NOISE IN THE NICU

The researcher carried out sporadic observations during the two 12-hour noise measurement periods in each of the two NICU rooms under investigation. She was able to observe everyday NICU activity and noise events, including scheduled events, such as infant care procedures, ward rounds and staff handovers. The researcher found that there was a multitude of noise sources in the NICU. The frequency of occurrence of the various noise events in the NICU was then noted, classified into one of the 13 categories, recorded on the checklist and converted into percentages of all noise events noted. The results are summarised in table 4.2 below.

Table 4.2: *Distribution of noise events observed in the NICU*

<u>Source</u>	<u>Room 1</u> <u>Day 1(%)</u>	<u>Room 1</u> <u>Day 2(%)</u>	<u>Room 2</u> <u>Day 1(%)</u>	<u>Room 2</u> <u>Day 2(%)</u>
Staff conversations	27.8	36.0	33.4	34.1
Bumping stainless cart or apparatus	3.5	2.3	2.7	2.3
Opening or closing trash can lid	7.8	4.0	2.0	3.4
Alarm of monitors	24.3	28.7	23.7	26.1
Care-giving (rubbing, moving or wrapping object) at open incubator	2.6	2.7	1.0	1.1
Multiple sources of noise	5.2	5.3	6.2	5.7
Telephone or pager ringing, intercom broadcasting, radio	7.0	6.3	7.3	8.1
Moving cart, chair and equipment	3.5	2.7	2.7	4.5
Handling equipment of oxygen supply	4.3	0	1.0	1.1
Cleaning apparatus and containers	3.5	2.7	2.7	2.3
Tearing plastic or paper bag	0.9	2.7	5.5	4.5
Bumping or cleaning the incubator	0.9	1.3	2.7	1.1
Others (infants crying, staff walking or running, dropping objects, conversations from family)	8.7	5.3	9.1	5.7
<i>Total</i>	<i>100%</i>	<i>100%</i>	<i>100%</i>	<i>100%</i>

Human-related factors, e.g., staff conversations, telephones, intercoms etc accounted for the majority of the noise event sources, equalling 65-70% of the noise events observed. This was quantified by adding up all the human-related sources of noise in table 4.2 above. This correlates well with the results of Chang et al. (2001), who found that about 90% of the loud noises in their study were related to personnel activities such as opening or closing incubator ports and conversation.

Numerous published studies have found that machinery in the NICU also contribute to the noise levels but to a lesser degree than staff activity (Benini et al., 1996; Elander & Hellström, 1995; Kent et al., 2002; Nzama et al., 1995). The results in Table 4.2 are in agreement with this statement and show that (the two main noise event sources observed in the present study were staff conversation and alarms of monitors.) while staff

conversations were always the largest single contributor (27.8 – 36%) to the number of noise events, the largest single non-human contributor to the noise sources was the alarm noise of the monitors (23.7 – 26.1%).

An “unquantifiable” source of noise in each room was a radio that was placed in the corner of the room. These radios were playing constantly throughout the measurement period, at approximately 68dBA, which was loud enough for the nursing staff to hear over and above the general noise in the NICU. Because the radio was on all the time during the measurements it could not be described as a “noise event”. However, it is important to note its presence as a contributor to the noise in the NICU.

The noise sources were very similar for both rooms. The slight differences in the frequency of observation of the noise events between the rooms may be owing to the fact that there was only one observer and fatigue may have had resulted in the slight differences between the two rooms and in the same room over the two day observation period. Regardless, certain events occurred more often in one room than in the other, such as handling the oxygen supply in room 1 and tearing plastic or paper bag in room 2 (two out of the 4 infants in room 2 had colostomy bags).

Additional Observations

There were only open incubators in the NICU rooms. The literature provides evidence of the differences in noise levels measured in open versus closed incubators. Good quality closed incubators have reduced noise levels compared to open incubators in the same measured environment, because of attenuation of sound by the incubator wall (Elander & Hellström, 1995; Saunders, 1995). An open incubator thus allowed for measurement of the highest noise levels an infant may be exposed to in a NICU room.

Closed incubators are, however, echoic chambers, which amplify noise levels of sound within the incubator (Bellieni, Buonocore, Pinto, Stacchini, Cordelli & Bagnoli, 2003). They often have cupboards underneath storing necessary equipment and belongings of the infant, while objects, such as bottles, patient files and X-rays, can be stored on top of

the incubator. Although the NICU rooms that were investigated only used open incubators, the infants were transferred and transported to and from the units to other rooms in the hospital in closed incubators.

Summary

Human-related noises contributed more than 65% of noise events. The largest single contributor to the number of noise events in the NICU were staff conversations (27.8 – 36%), while the alarm noise of the monitors was the largest single non-human contributor (23.7 – 26.1%).

4.3 NEONATES' PHYSIOLOGICAL RESPONSES TO NOISE IN THE NICU

One of the specific aims of the study was to attempt to investigate potential relationships between the noise levels in the NICU and infants' physiological responses. Initially, it was necessary to attempt to determine trends in the infants' physiological responses over the two days and between rooms. Only heart rate and respiratory rate were analysed statistically, because these were the only consistent variables monitored in all of the subjects whose parents' had consented to their participation in the study. Oxygen saturation and blood pressure could only be measured for 3 of the subjects and it was decided that, due to the very small sample size (6 subjects), only those variables measured for all infants would be analysed, that is respiratory- and heart rates.

Heart Rate

Repeated measures ANOVA was conducted to determine if an interaction existed between the 12 dependent variables (heart rate averaged at hourly intervals over each of the twelve-hour measurement periods) and the category predictors: each room over the two days per room. Table 4.3 below illustrates the analysis done and the significant interactions (or relationships) are highlighted in red.

Table 4.3: Results of repeated measures ANOVA for heart rate and category predictors

<i>Effect</i>	SS	Degree of Freedom	MS	F	P
Intercept	2792972	1	2792972	1650.700	0.000000
Room	589	1	589	0.348	0.571499
Day	20	1	20	0.012	0.916424
Room*Day	2979	1	2979	1.761	0.221168
Error	13536	8	1692		
Time	3328	11	303	2.858	0.003012
Time*Room	2646	11	241	2.272	0.017170
Rime*Day	936	11	85	0.804	0.635951
Time*Room*Day	969	11	88	0.832	0.608602
Error	9315	88	106		

A significant interaction (or relationship) was found between the hourly averaged heart rates for all the infants and the room in which the measurement occurred. Heart rates seemed to be generally higher on day 1 than day 2 in room one (figure 10). Further analysis utilising the Bonferroni procedure [a multiple comparison procedure used to determine where the interaction/difference occurred (Dunn & Clarke, 1974)] indicated that this interaction occurred during the 5th hour of measurement and was only found in room 1.

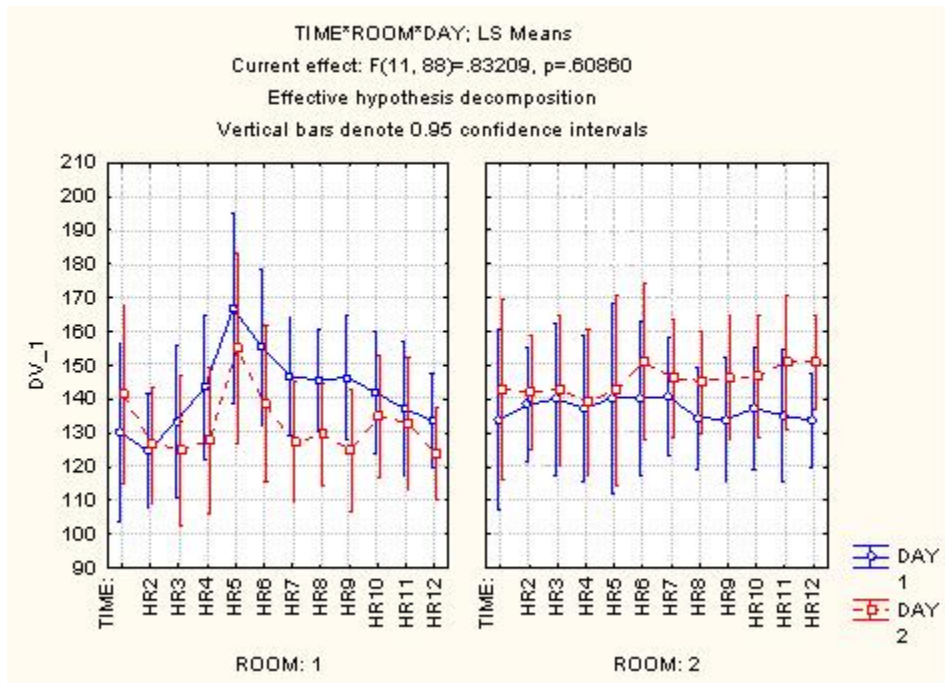


Figure 4.8: Graph illustrating the repeated measures ANOVA regarding heart rate

From figure 4.8 above, it can be seen that the heart rates for the infants in room 2 remained fairly consistent during the 12-hour measurement period on both days. However, it can be seen that in room 1, although starting at a relatively low level during the first 3-4 hours, the infants' heart rates increased rapidly during the 5th hour of measurement and then decreased reaching a plateau similar to the results in room 2 from the 6th hour onward on both days. No obvious cause could be found for this significant interaction. Nothing remarkable occurred in room 1 on either day that did not occur in room 2.

Respiratory Rate

Repeated measures ANOVA was also utilised to determine if an interaction existed between the 12 dependent variables (respiratory rate averaged at hourly intervals over each of the twelve-hour measurement periods) and the category predictors: each room over the two days per room. Table 4.4 below illustrates the analysis done.

Table 4.4: Results of repeated measures ANOVA for respiratory rate and category predictors

<i>Effect</i>	SS	Degree of Freedom	MS	F	p
Intercept	152193.6	1	152193.6	47.29137	0.000236
Room	9.8	1	9.8	0.00306	0.957458
Day	2552.8	1	2552.8	0.79324	0.402694
Room*Day	1455.5	1	1455.5	0.45227	0.522839
Error	22527.5	7	3218.2		
Time	902.3	11	82.0	0.85383	0.587955
Time*Room	455.1	11	41.4	0.43064	0.937720
Rime*Day	649.6	11	59.1	0.61470	0.810923
Time*Room*Day	802.8	11	73.0	0.75968	0.678284
Error	7397.1	77	96.1		

No significant interactions or differences were found. Figure 4.9 below illustrates this finding. It can be seen that respiratory rates remained fairly consistent over time in each of the rooms over both 12-hour measurement periods in each of the two rooms.

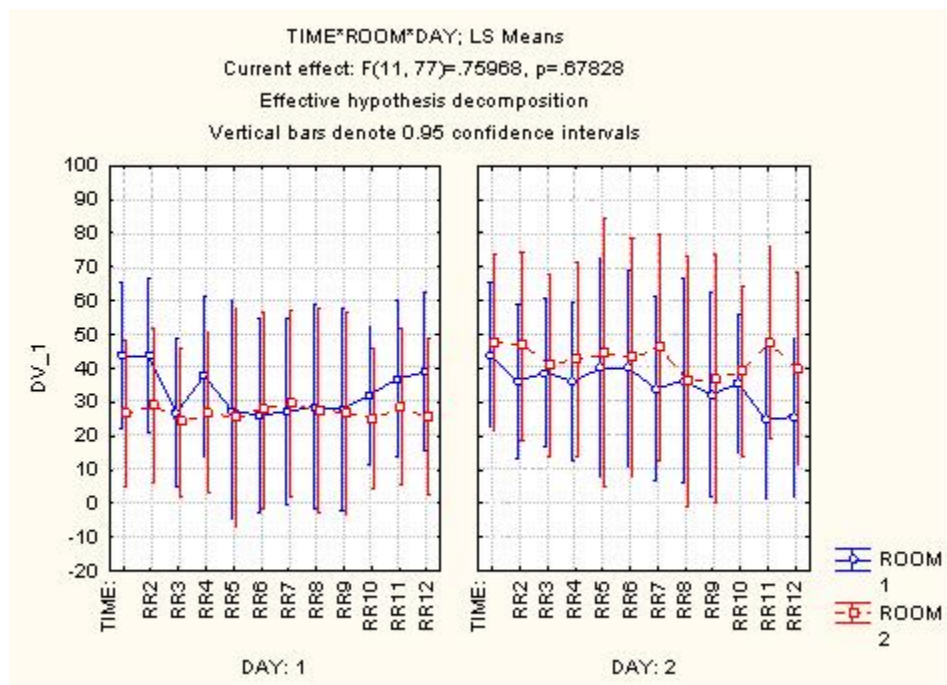


Figure 4.9: Graph illustrating the repeated measures ANOVA regarding respiratory rate

Correlations of heart- and respiratory rate with noise level

Finally, correlations of heart- and respiratory rates with the noise levels were calculated per participant and as well as the correlations of the average heart- or respiratory rate of the participants with the noise levels in each room. This was done to determine if and how the heart- and respiratory rate were influenced or not by the noise levels measured.

Initially, it was necessary to determine if the noise levels and the heart- and respiratory rates of the neonates were normally distributed and this was conducted using the Shapiro-Wilk test for normality of data. The null hypothesis that the noise levels and the heart- and respiratory rate data were normally distributed was rejected ($p < 0.05$) by the Shapiro-Wilk test and so a further test for correlation using the Spearman correlation coefficient was done. It was found that in general, the values were not normally distributed, which indicates that there were no significant correlations between the heart rate and noise levels and the respiratory rate and the noise levels for any of the participants in either room (see figures 4.10-4.13 below).

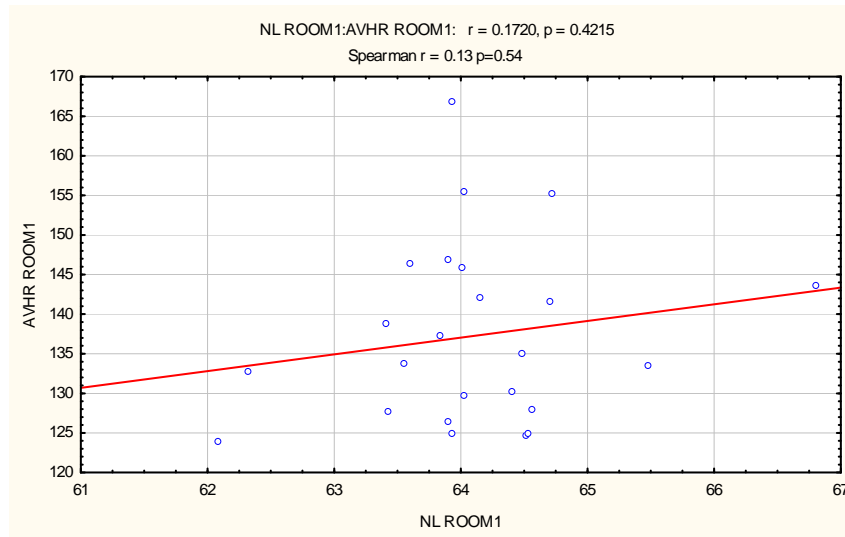


Figure 4.10: Graph illustrating Spearman's correlation for the averaged heart rates of the neonates in room one and the noise levels

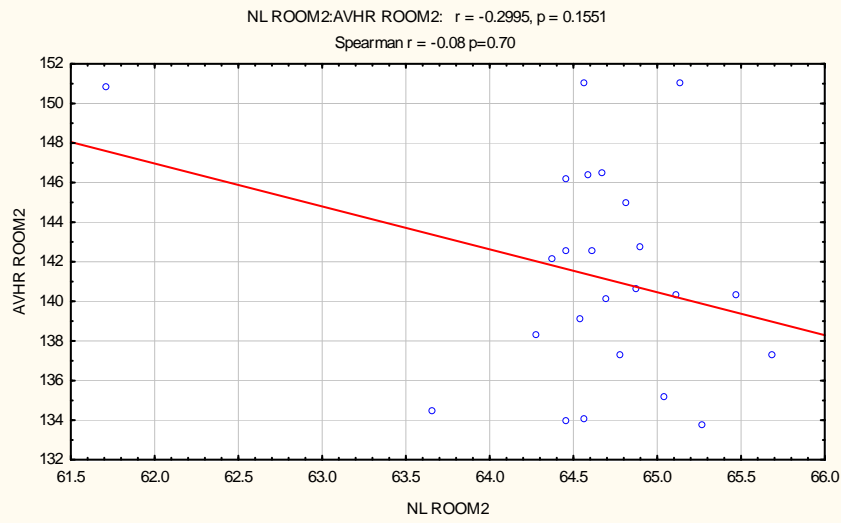


Figure 4.11: Graph illustrating Spearman's correlation for the averaged heart rates of the neonates in room two and the noise levels

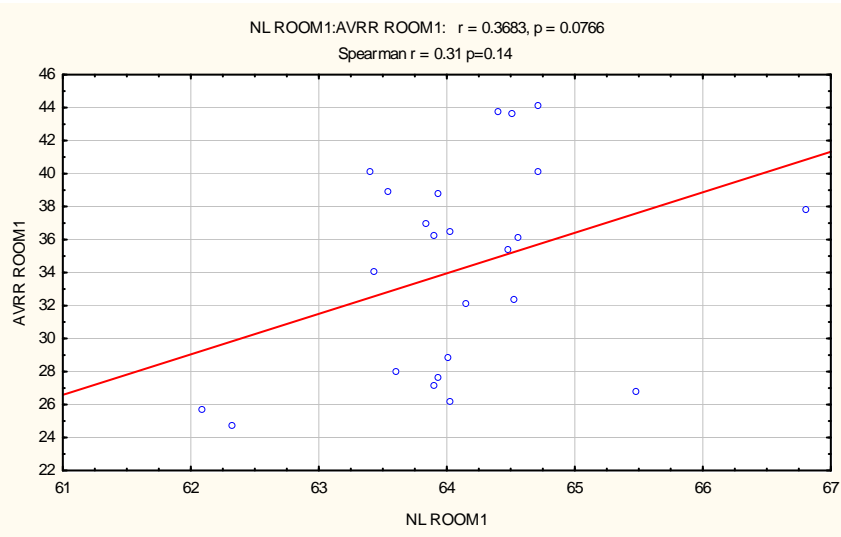


Figure 4.12: Graph illustrating Spearman's correlation for the averaged respiratory rates of the neonates in room one and the noise levels

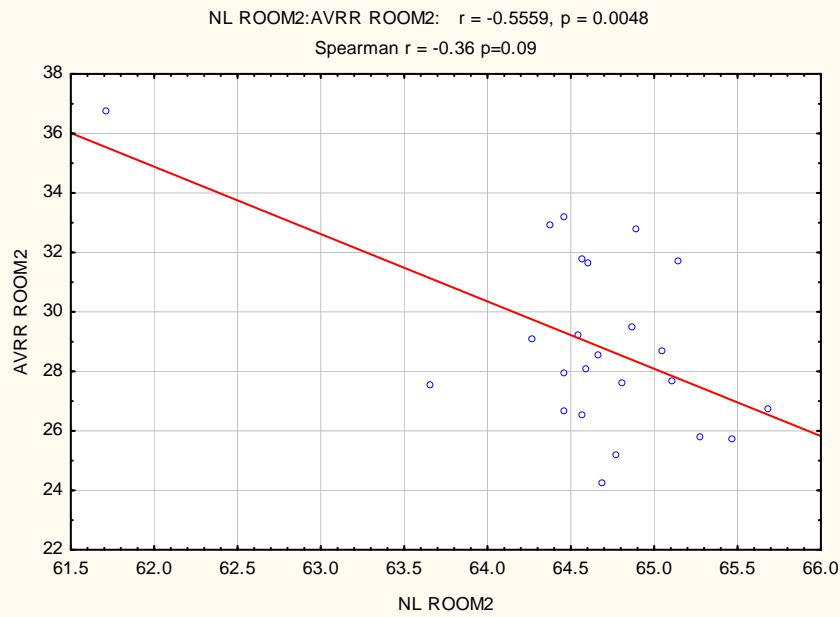


Figure 4.13: *Graph illustrating Spearman’s correlation for the averaged respiratory rates of the neonates in room two and the noise levels*

The current study did not find any significant correlation between the noise levels in the NICU and the heart- and respiratory rates of the neonates in the NICU. Essentially this suggests that the high noise levels and their variations in the NICU did not seem to influence the infants’ heart and respiratory rates. This is contradictory to the results found and published in studies such as Long et al. (1980) and Zahr and Balian (1995), who documented the effects loud noise events on the physiological and behavioural responses of preterm neonates in the NICU. Perhaps, the very small sample size of the present study may have contributed to the lack of correlation found between the variables under investigation.

Summary

Statistical analyses revealed a significant interaction between the hourly averaged heart rates for all infants and the room in which the measurement was taken. This occurred during the 5th hour of measurement and was only found in room 1. This did not seem to be related to noise level changes and no obvious behavioural cause could be found for

this interaction. No significant interactions were found between respiratory rates and the category predictors.

4.4 REVERBERATION MEASUREMENTS

The actual reverberation times measured for each pre-determined frequency were as follows (see below in figure 4.14):

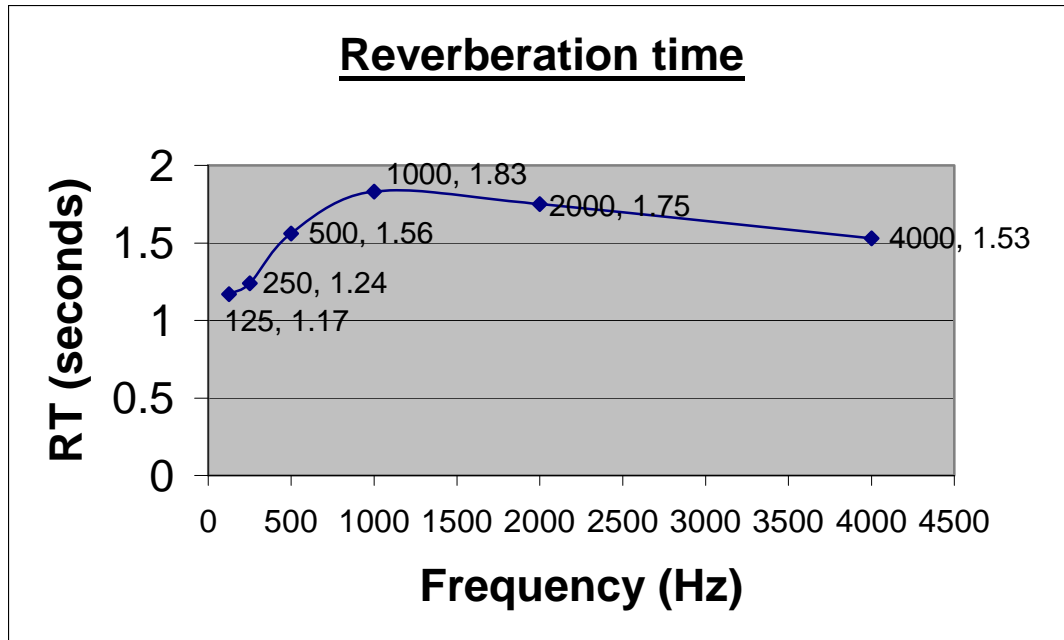


Figure 4.14: Graph depicting actual reverberation time of the “empty” room

The volume of the room was calculated as 134m³. Using Sabine’s mathematical equation (Alton Everest, 2001) and the measurement times from the actual reverberation measurements, the total absorption values for each pre-determined frequency was calculated as follows (for example):

$$A_{125} = \frac{0.161 \times 134}{1.17} = 18.43 \text{ m}^2 \text{ Sabine}$$

The total absorption values for each pre-determined frequency were as follows:

125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
18.43	17.40	13.83	11.79	12.33	14.10

In order to determine the co-efficient values of absorption for the room, it was necessary to calculate the room surface area of the empty room (assuming the door was closed), which was 172m². The co-efficient values of absorption were then calculated for each of the pre-determined frequencies by dividing the total absorption value (as above) for each frequency by the room surface area. The results of which were the following:

125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
0.11	0.10	0.08	0.07	0.07	0.08

According to T. Mackenzie-Hoy (personal communication, November 2006), these values indicate extremely poor absorption of the room surface areas.

Although the reverberation measurements took place in an empty room of similar dimension to the NICU rooms that were investigated, it is necessary to take into account that the NICU rooms are not empty. Assuming that there are 6 open incubators in each of the NICU rooms and assuming each incubator is 1m x 1m, and has an absorption co-efficient of 0.5 across all frequencies, the total absorption of the incubators is:

- $6 \text{ incubators} \times 1\text{m}^2 \times 0.5 \text{ (at all frequencies)} = \underline{3}$

Thus the total absorption values (taking the incubators into account) would be as follows:

125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
18.43	17.40	13.83	11.79	12.33	14.10
+3	+3	+3	+3	+3	+3
= <u>21.43</u>	= <u>20.40</u>	= <u>16.83</u>	= <u>14.79</u>	= <u>15.33</u>	= <u>17.10</u>

Using Sabine's equation, estimated reverberation time for each frequency could be determined for the NICU rooms that were investigated (for example):

$$RT_{125} = \frac{0.161 \times 134}{21.43} = 1.00 \text{ seconds}$$

Similarly, the estimated reverberation time for each pre-determined frequency in the NICU room would be as follows:

125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
1.00	1.06	1.28	1.46	1.41	1.26

The estimated reverberation time values are marginally quicker for the NICU rooms than those that were measurement in the “empty” room. This means that the open incubators should play a role in absorbing some of the noises in the NICU, thereby marginally improving the acoustics of the NICU room.

The estimated reverberation time values were then entered into an equation measuring the SPL (dBA) of the average number of people in the NICU at one time (as used in the calculations in Sabine’s equation) talking at an average volume level. This value, together with the actual noise measurement values obtained, indicated that the NICU rooms were extremely reverberant environments and it is probable that the noise level in the NICU was to a significant degree a result of reverberant noise from NICU room reinforcements. Additional calculations altering reverberation time, found that if reverberation time was reduced, it would result in a sufficient reduction of the sound pressure level in the room. This would potentially be the most cost-effective way of reducing noise levels in the NICU.

In practical terms, this means that the hospital building acoustics as well as the room acoustics were poor. The literature states that reverberation time is related to volume (of the room) (V) and absorption of materials and objects in the room: in other words, the greater the room, the greater the room volume, the greater the reverberation time, but the more absorbent materials and objects in a room, the less the reverberation time (Durrant & Lovrinic, 1995). Observations by the researcher suggested that very few absorbing materials had been used in the NICU to try “absorbing” some of the reverberant and ambient sound of the unit and the hospital, such as heating, ventilation and air-conditioning systems, plumbing, vibration and communications. There were no carpets, acoustic tiles or curtains in either of the two rooms, which would have helped improve the acoustic conditions in the unit, in reducing the noise levels.

In a study that measured the noise levels in a single, empty NICU before and after a staff education program regarding the effects of NICU noise and a third time after a minor renovation to the physical space in the NICU, Philbin and Gray (2002) found that the NICU, even when empty, was never quiet. This is similar to the results of the present study, in that the actual room in which the NICU is situated is highly reverberant, which is further contaminated by poor hospital building acoustics. Additionally, the only other study on noise levels in a private hospital NICU in South African did not consider NICU building acoustics and so it is difficult to correlate results found.

It must be noted that the NICU rooms were not designed to be as such. All wards in the hospital were initially designed as general wards, when issues surrounding guidelines and recommendations for critical, high or intensive care units were not followed (Prof. G. Kirsten, personal communication, March 2006). So it makes sense that acoustics of the actual NICU rooms do not match the standards of health building design or NICU room design, stipulated in the recommendations by the Third Consensus Conference on Newborn ICU Design (1996) and the South African SABS 0218, Part 1 - 1999 standard ('Acoustical properties of buildings Part 1: Grading criteria for the airborne sound insulation properties of buildings'), which indicates that the NICU should be an environment that is acoustically friendly to the neonate.

Summary

It was found that the NICU was an extremely reverberant environment and the level of noise in the NICU was to a significant degree judged to be a result of reverberant noise from NICU room reinforcements. Practically, this implies that the hospital building acoustics as well as the room acoustics were poor.

4.5 FEEDBACK TO THE NURSING STAFF

The following suggestions for noise abatement strategies were made by the nine nursing staff that responded, listed in order of most often suggested to least often suggested (with percentage of "votes" each recommendation received in brackets after each suggestion):

- i) Reduce staff generated noise by increasing awareness of noise levels and the damaging effect that it has on patients through staff training (100%)
- ii) Conversations should not be held at the bed side, especially not over the patient in the radiant warmer (78%)
- iii) Turn off and remove the radio from the unit or only play very soft music through the advice of a consultant (67%)
- iv) Alarm volumes should not be decreased but the staff should respond to alarms immediately and silenced before attending to the infant (56%)
- v) Blinds or curtaining can be fitted to increase absorption of noise; however these may increase the risk of infection. Carpets are also not an option due to the risk of infection, whilst vinyl flooring is easier to clean and maintain (44%)
- vi) The constant pulse sound on the oxygen saturation monitors can be turned off, but not the alarm volume (33%)
- vii) Other recommendations by a single staff member
 - Reduce the ringing volume of the telephones (11%)
 - Metal dust bins should be replaced with plastic or “noise-less” devices (11%)
 - If finances are available, acoustic reducing building material can be introduced (11%)
 - Ideally, funds allowing, a dB monitor with set limits can be installed to increase awareness and with flashing lights, be a reminder of unacceptable noise levels (11%)
 - Some staff may have hearing loss, so staff hearing screening is recommended (11%)

Bremmer et al. (2003) indicates that although environmental NICU noise cannot always be controlled because of the equipment used to sustain life, there are numerous ways of reducing noise levels in the NICU. Several published studies have mentioned similar noise reduction strategies to the suggestions cited above (Anagnostakis et al., 1980; Elander & Hellström, 1995; Gray et al., 1998, Long et al., 1980; Robertson et al., 1999).

It is apparent that the main recommendations provided by the nursing staff were directly related to the outcomes of the study (that is, related to reducing staff conversation, alarm volumes and radio noise). Most of the other recommendations were suggested by single respondents. The majority only made two or three suggestions. Only 1 of the 9

respondents returned the suggestion form complete with ten suggestions. Perhaps the outcome might have been different, if the original plan of feedback and suggestion collection had taken place through a focus group feedback discussion.

According to Bremmer et al. (2003), there are two approaches that can be taken to reduce NICU noise levels: (A) a plan involving major renovations, which can be quite costly; (B) a plan utilising relatively simple strategies to reduce noise levels, which have little or no cost. Suggestion v and some of vii fall into plan A, while the rest fall into plan B.

With regards to suggestions i and ii above, it is important to highlight the fact that keeping conversation to a minimum near the patient is not easy to adopt, because the nursing staff have to keep reminding themselves to do so in the NICU (Aita & Goulet, 2003). It might be an idea to put up 'reminder' signs in the NICU, such as "babies sleeping" or "lower your voice". However, it must be noted that according to Philbin (2000), those programmes that combined staff education about noise with the intention of reducing staff noise levels, have had only temporary or limited success.

DePaul and Chambers (1995) pointed out that nursing staff may become accustomed to the noise in the NICU and consequently may not readily respond to the alarms, which results in an increase in the background noise level in the NICU. So suggestion iv above may be difficult to implement and would possibly require the head of the unit to monitor that staff improve their response time to the alarms.

Suggestion v was made regarding floor, ceiling and window surfaces. According to the Third Consensus Conference on Newborn ICU Design (1996), careful consideration should be given to floor surfaces and ceiling finishes, which should respectively include resilient sheet flooring or carpeting and acoustic tiles. This would obviously be for an ideal financial situation. However, the nursing staff felt that carpeting and curtains might increase the risk of infection spreading to the neonate and may jeopardise their health.

Additionally, both NICU rooms had ventilation and heating and air conditioning systems with a ducting vent in the centre of each room. It is vital that hospital maintenance staff regularly clean the filter and air-vents to ensure that dirt and dust trapped is thoroughly eliminated to ensure minimal contamination to the NICU itself (Third Consensus Conference on Newborn ICU Design, 1996).

Summary

Most suggestions by the nursing staff related to simple noise reduction strategies with little or no cost implications, such as reduction of staff conversation (which was the most commonly noted suggestion). Few suggestions were related to NICU renovation.

5. CONCLUSIONS, CRITIQUE AND IMPLICATIONS

This study conducted a detailed noise assessment in a NICU of a state hospital in the Cape Metropole and documented infant responses to these levels. The five stages of data collection yielded the following findings:

1. The noise levels found in the present study ranged from 62.3-66.7dBA (L_{Aeq}). These noise levels exceed all recommendations for NICU's of 50dBA to 60dBA (Levy et al., 2003; Philbin et al., 1999; Third Consensus Conference on Newborn ICU Design, 1996). Continuous exposure to this high noise levels during an infant's stay in the NICU is potentially harmful to the infants' health stability and to the auditory system (American Academy of Pediatrics, 1997). The measured noise levels may also be detrimental to staff hearing and health.
2. Thirteen categories of noise events were observed. Staff conversations were always the largest single contributor (27.8 – 36%) to the number of noise events, while the largest single non-human contributor to the noise sources was the alarm noise of the monitors (23.7 – 26.1%).
3. An investigation of relationships between the noise levels in the NICU and infants' physiological responses: heart rate and respiratory rates were analysed statistically. A significant interaction was found between the hourly averaged heart rates for all the infants and the room in which the measurement occurred. This interaction occurred during the 5th hour of measurement and was only found in room 1. No obvious cause could be found for this interaction. No significant interactions were found between respiratory rates and the category predictors
4. In an attempt to determine whether the noise levels in the NICU was a result of direct noise or reverberant noise from NICU room reinforcements, reverberation times were measured. It was found that the NICU rooms were extremely reverberant environments. It appeared that the level of noise in the NICU was to a significant degree

a result of reverberant noise from NICU room reinforcements. In practical terms, this meant that the hospital building acoustics as well as the room acoustics were poor.

5. The results of the study were given to the nursing staff in the NICU and they were asked to give suggestions for NICU noise abatement strategies. Reduction of staff conversation was the most frequently suggested strategy for noise reduction. Most of the suggestions by the nursing staff related to simple noise reduction strategies with little or no cost implications. Few suggestions also made reference to the more costly NICU reconstruction or renovation, which may not be possible due to financial constraints.

Critique

Researchers must evaluate their research in order to identify the limitations of their study and therefore possible directions for future researchers (Silverman, 1993).

Noise level measurements

Each method of noise measurement procedure has its strengths and weaknesses. This study utilised the central site procedure, similar to that used by Robertson et al. (1998) and Levy et al. (2003). This procedure is recommended to assess the overall measures of general NICU sound and to capture a more realistic, valid and natural range of noise in the NICU (Gray & Philbin, 2000; Robertson et al., 1998). There was only one SLM available for a limited time period and so taking noise level measurements within each of the incubators in the NICU room would have been difficult and time-consuming.

Noise level measurements in this study were recorded by placing the microphone of the SLM in the centre of the room at a height of 195cm. It sought to measure the general noise levels in each of the NICU rooms and not specific sites in the NICU, such as inside incubator. It is less conspicuous and invasive than moving the microphone and SLM to different areas in the NICU (Gray & Philbin, 2000).

The central site procedure worked well in this study. It captured the “general” noise levels in each of the NICU rooms. Although the nursing staff initially were aware of the

measurements taking place, it was felt that noise level measurements were an accurate reflection of the actual noise levels in the NICU rooms at this hospital.

Had the researcher conducted specific measurements of the noise levels in each of the incubators in the NICU, the staff working on those infants might have been more aware of the microphone placed by the infants head and thus might have been more likely to alter their "normal" behaviour. Placing the microphone in the incubator by the infant's head would have been more invasive and there may have been a possibility of the infant moving and knocking themselves against the microphone. On the other hand, taking specific in-situ incubator measurements might have yielded a more representative sample of the full spectrum of NICU activities that produce noise and the actual noise levels to which each of the infants in the NICU was exposed.

Despite the many advantages of utilising the central site procedure, it is imperative to mention certain limitations with this method of noise level measurement. These include the possibility of unmeasured sound variability in a large room, noise reflection and distortion by varied room materials, equipment, or heating, ventilation and air-conditioning as well as spacing of infants in the incubators and associated equipment in a large room (Gray & Philbin, 2000; Robertson et al., 1998). Being aware of the above-mentioned limitations of the central site procedure, the researcher selected this measurement method.

Observation of the noise sources

The presence of the researcher might have initially influenced the behaviour of the staff in the NICU, thereby affecting the frequency of occurrence of certain noise events. This could have possibly been partially avoided by having an independent research assistant with a more long-term presence, observe the noise sources.

Physiological responses

A more thorough evaluation of the relationships between the noise levels and various physiological responses could have been conducted if it had been possible to record all

the vital signs for each of the six infants who participated in the study. The fact that only two variables, heart - and respiratory rate, were measured for the only six infants may have resulted in the less conclusive results in the present study.

Reverberation measurements

An attempt was made to remove the furniture and equipment housed in the “empty” room, used for the reverberation time measurements. The room was at the time being used as a meeting room and for the medical students’ oral examinations. However, some of the equipment, like a 3m boardroom table and a small fridge were too heavy to move. During the analysis of the results, the remaining items were taken into consideration. The best practice would have been to empty the room of all of the items to conduct the measurements.

Feedback to the nursing staff

The use of a questionnaire-type feedback and response format for the nursing staff was not initially planned. However, due to lack of time and shortage of staff, it was decided to use this as the means to correspond with the nursing staff. This tool for data collection is not ideal because the nursing staff may have given answers that did not necessarily reflect their own thoughts. They also may have used the opportunity to discuss their answers and use each other’s ideas. The small sample size (9) of respondents did not allow for the generalisation of the results, which constitutes another limitation.

Practical Implications

The effect of the levels of noise found in the current study on both the neonate and on nursing and other staff as well as the parents of the neonates have been documented in the literature (Allen et al., 2002; American Academy of Pediatrics, 1997; Blackburn, 1998; Bremmer et al., 2003; DePaul & Chambers, 1995; Long et al., 1980; Zahr & Balian, 1995). Effects on the neonate could be hearing impairment, changes in sleep/wake patterns, alterations in cardiovascular and respiratory rates (although no significant interactions were found in the present study) as well as oxygen saturation rates.

Adult reactions to noise include fatigue, impaired judgement, irritability and altered perceptions, which may make NICU staff more prone to errors in patient care (DePaul & Chambers, 1995). In addition, exposure to constant noise may potentially result in noise induced hearing loss. Thus it is suggested that staff members working in the NICU undergo annual hearing screening in order to assess their hearing acuity and to monitor their hearing status.

These effects warrant significant attempts to be made in order to reduce noise levels in the NICU, to facilitate and promote health, growth and wellbeing for both the neonates and the adults in the NICU (staff and parents). There are two types of approaches, according to Bremmer et al. (2003), that can be taken to reduce noise levels in the NICU: (A) renovation/construction of the NICU (which can be quite costly), such as utilizing acoustically treated surfaces and rearranging beds to be as far from nursing stations and sinks as possible; (B) simple clinical intervention strategies to reduce noise levels, which have little or no cost, such as responding quickly to alarms and crying infants and reducing staff conversation and ward rounds by the bed of the neonates.

Implications for Research

The importance of investigating noise levels in the NICU and the effects of the noise on the neonates and even staff in these units has been well documented in a number of internationally published studies. Little research, however, has been carried out in South Africa.

Zahr (1998) compared the physiological and behavioural responses of infants in two modern NICUs in Los Angeles, USA with the responses of infants in a less technologically advanced NICU in Beirut, Lebanon. The author found that the NICU in Beirut was quantitatively less noisy and the nursing activities less intrusive than in the two NICUs in Los Angeles (due to the less advanced medical technologies utilised and the high infant-to-nurse ratio – 4-6 infants per nurse). It would be interesting to compare the levels of noise in private and state NICU's in South Africa. Currently, there appears to be very little interaction between state and private hospitals in South Africa with

regard to patient care and sharing of equipment. Infants are “*transferred from private to public [state] hospitals mainly because of inadequate medical aid funds to pay for further medical care in a private hospital*” (Paediatric Neonatology Workgroup, 2003, p.3). Although the standards of care are generally good (Paediatric Neonatology Workgroup, 2003), state hospitals in South Africa have potentially less resources available to comply with acceptable standards of practice, including state of the art equipment, finances and recruitment and retaining of nursing staff (Associate Prof. S. Clow, personal communication, April, 2005; Dr. M.E. Bester, personal communication, April, 2005).

It would also be interesting to assess how well the design of existing facilities comply with suggested noise standards. In addition, evaluation of existing noise management/reduction strategies and their effectiveness in South African NICUs would be of interest.

Final Thought

The results of this study highlight the need for NICU noise abatement, which is vital to reducing the risk of acoustic trauma, optimising newborn patient care and improving the neonate’s quality of life, thus enhancing the infant’s physiologic stability, growth and health. It is imperative that nursing and other staff in the NICU take responsibility for identifying and reducing stimuli in the NICU in order to facilitate and develop an environment that is acoustically-friendly to the neonate. As Benini et al. (1996, p.40) states: “*It is surprisingly easy to change the situation by arousing general awareness of the [noise] problem, adopting useful means for reducing environmental noise and teaching nursing and medical personnel to control noise*”.

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7. APPENDICES

Appendix A: Ethical approval to conduct the study by the Research Committee at the Stellenbosch University



UNIVERSITEIT-STELLENBOSCH-UNIVERSITY
jou kennisvermoë • your knowledge partner

30 May 2006

Ms LM Nathan
Discipline of Speech-Language and Hearing Therapy
Department of Interdisciplinary Health Sciences

Dear Ms Nathan

RESEARCH PROJECT: "NOISE LEVELS IN A NEONATAL INTENSIVE CARE UNIT OF A STATE HOSPITAL IN THE CAPE METROPOLE"
PROJECT NUMBER : N06/04/066

At a meeting of the Committee for Human Research that was held on 3 May 2006 the above project was approved on condition that further information that was required, be submitted.

This information was supplied and the project was finally approved on 29 May 2006 for a period of one year from this date. This project is therefore now registered and you can proceed with the work. Please quote the above-mentioned project number in all further correspondence.

Please note that a progress report (obtainable on the website of our Division) should be submitted to the Committee before the year has expired. The Committee will then consider the continuation of the project for a further year (if necessary).

Patients participating in a research project in Tygerberg Hospital will not be treated free of charge as the Provincial Government of the Western Cape does not support research financially.

Due to heavy workload the nursing corps of the Tygerberg Hospital cannot offer comprehensive nursing care in research projects. It may therefore be expected of a research worker to arrange for private nursing care.

Yours faithfully

CJ VAN TONDER
RESEARCH DEVELOPMENT AND SUPPORT (TYGERBERG)
Tel: +27 21 938 9207 / E-mail: cjvt@sun.ac.za

CJVT/ev

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Fakulteit Gesondheidswetenskappe • Faculty of Health Sciences



Verbind tot Optimale Gesondheid • Committed to Optimal Health
Afdeling Navorsingsontwikkeling en -steun • Research Development and Support Division
Posbus/PO Box 19063 • Tygerberg 7505 • Suid-Afrika/South Africa
Tel: +27 21 938 9677 • Faks/Fax: +27 21 931 3352
E-pos/E-mail: rdsinfo@sun.ac.za

Appendix B: Permission to conduct the study by the Medical Superintendent of Tygerberg Academic Hospital



**Departement van Gesondheid
Department of Health
ISebe lezeMpilo**



Verwysing
Reference
Isalathiso

Navree
Enquiries
Imibuzo

Dr J H Groenewald

Telefoon
Telephone
Howuni

(021) 838-4014

Datum
Date
Umhla

6 July 2008

Tygerberg Akademiese Hospitaal e
Mitchellsplein & Tygerberg Mondgesondheidsentrum

Tygerberg Academic Hospital an
Mitchells Plain & Tygerberg Oral Health Centre

Iubhadjele Sase Tygerberg Kwakunye N
Mitchele Plain Neziko Lamazinyo Lase Tygerber

Privaatsak X3/ Private Bag X
Tygerberg, 750

Fax to: (021) 439-0702

For Attention: Ms Lisa Nathan

Dear Ms Nathan

RE: PERMISSION TO CONDUCT A STUDY

I refer to your fax regarding the above received this morning.

Permission is hereby granted to you to conduct the study 'Noise Levels in a Neonatal Intensive Care Unit of a State Hospital in the Cape Metropole' at the Tygerberg Academic Hospital.

Yours sincerely,

J H Groenewald

pp **Dr J H Groenewald**
SENIOR EXECUTIVE
JHG/lab/Groen Research

Appendix C: Consent form for parent/guardian of neonates occupying open incubators in the NICU (English)

**UNIVERSITY OF STELLENBOSCH
FACULTY OF HEALTH SCIENCES
DISCIPLINE OF SPEECH-LANGUAGE AND HEARING THERAPY**

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM

TITLE OF THE RESEARCH PROJECT: Noise levels in a neonatal Intensive Care Unit of a state hospital in the Cape Metropole

PRINCIPAL INVESTIGATOR: Lisa Nathan

SUPERVISORS: Prof. S.K. Tuomi and A. Muller

ADDRESS: Discipline of Speech-Language and Hearing Therapy
PO Box 19063
Tygerberg 7505

CONTACT NUMBER: 082-855-4133

Dear Parent/Guardian

You are being invited to take part in a research project. Please take some time to read the information presented here, which will explain the details of this project. It is very important that you are fully satisfied that you clearly understand what this research entails and how you could be involved. Your participation is **entirely voluntary** and you are free to decline to participate. If you say no, this will not affect you or your baby negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

This study has been approved by the **Committee for Human Research at Stellenbosch University** and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki, South African Guidelines for Good Clinical Practice and the Medical Research Council (MRC) Ethical Guidelines for Research.

1. What is this research study all about?

I am doing this study to look at the noise levels in a neonatal intensive care unit (NICU). Loud noise levels have been found to adversely affect the baby. This study is going to be done by one researcher. It is hoped that this study will give information about the loudness of the noise levels in the NICU so that it can be used to come up with plans that will help lower noise levels for the babies in the NICU.

2. Inclusion criteria

Your baby will have to have his/her hearing tested to make sure that s/he hears the sounds in the room before s/he can be included in the study. Two tests will be done to make sure if s/he can hear.

- i. Test 1: This is done by holding sticking small stickers on your baby's head and then sticking earphones over both ears. Clicking sounds will be sent into both ears at the same time. It will then read if your baby passes the test, which suggests normal ear function. If your baby passes, s/he will be included in the study.
- ii. Test 2: This is done by putting a soft plastic probe into your baby's ear (one ear at a time) and sends a click sound into the ear. It will then read if your baby passes the test, which suggests that hearing is normal. If your baby passes, then s/he will be included in the study.

You will be told the results of the hearing tests as soon as the testing is finished. If it is found that your baby did not pass the hearing screening, you will be advised what further steps to take and referrals will then be made.

3. Description of the research project

1 Noise level measurements:

Noise levels will be measured using a battery operated noise-measuring machine in both NICU rooms and will be made over 2 day-shifts per room from 08h00 till 20h00.

2 Reactions of the baby to the noises in the NICU:

Printouts will be made from the machines monitoring the infants' vital signs (such as heart rate and breathing rates). This information will be put onto a checklist.

4. Confidentiality of information collected

No names will appear in the study. All information will be coded by number only in any reports on this study. All records will be kept confidential.

5. Risks and discomforts of the research

All babies whose parents/guardians have given permission for them to take part in the study will have to have their hearing tested (tests described above in number 2). This will make sure that they can hear the sounds in the NICU. Neither test is painful or harmful to your child. The information from the tests will be given to you immediately after testing and will be told to your baby's doctors. This information and other information from the study will hopefully improve the noise conditions in the NICUs.

6. Expected benefits to you and to others

You or your child will not benefit directly from this study, other than knowing your baby's hearing status. But what is learnt from this study can be used to improve the systems monitoring the noise levels in the NICU and improve ways to lower the noise levels in the NICU.

7. Costs to you resulting from participation in the study

There will be no cost involved.

8. Contact person

You may contact one of the following persons for answers to further questions about the research, your rights, or any injury you may feel is related to the study.

Stellenbosch University Researchers: Ms Lisa Nathan (researcher) – Tel: 082-8554133

Prof. S.K. Tuomi (supervisor) – Tel: 021-9389163

9. Is there any thing else that you should know or do?

- 1 You can contact the Committee for Human Research at 021-938 9207 if you have any concerns or complaints that have not been adequately addressed.
- 2 You will receive a copy of this information and consent form for your own records.

Declaration by participant

By signing below, I agree for my child to have his/her hearing tested and if s/he passes, to further take part in a research study entitled - *Noise levels in a neonatal Intensive Care Unit of a state hospital in the Cape Metropole.*

I declare that:

- 1. I have read or had read to me this information and consent form and it is written in a language with which I am fluent and comfortable.
- 2. I have had a chance to ask questions and all my questions have been adequately answered.
- 3. I understand that taking part in this study is **voluntary** and I have not been pressurised to take part.
- 4. I may choose to leave the study at any time and will not be penalised or prejudiced in any way.

Signed at (place) on (date) 2006.

.....
Signature of participant

.....
Signature of witness

Declaration by investigator

I (name) declare that:

- 1. I explained the information in this document to
- 2. I encouraged him/her to ask questions and took adequate time to answer them.
- 3. I am satisfied that s/he understands all aspects of the research, as discussed above
- 4. I did/did not use a translator.

Signed at (place) on (date) 2006.

.....
Signature of investigator

.....
Signature of witness

Thank you in anticipation of your co-operation.
Yours faithfully

.....
Lisa Nathan (Audiologist)

.....
Prof. S.K. Tuomi (Supervisor)

Appendix D: Checklist of the noise events in the NICU

<u>Source</u>	<u>Number of occurrences</u>
Staff conversations	
Bumping stainless cart or apparatus	
Opening or closing trash can lid	
Alarm of monitors	
Caregiving (rubbing, moving or wrapping object) at warmer bed	
Multiple sources of noise	
Telephone or pager ringing, intercom broadcasting, radio	
Moving cart, chair and equipment	
Handling equipment of oxygen supply	
Cleaning apparatus and containers	
Tearing plastic or paper bag	
Bumping or cleaning the warmer bed	
Others (closing or opening drawers at the station, crying from other infants, staff walking or running, dropping objects, conversations from family)	
Additional sources: _____ _____	

NOISE LEVELS IN A NEONATAL INTENSIVE CARE UNIT
IN THE CAPE METROPOLE

Lisa Nathan

SUMMARY OF THE FINDINGS OF THE STUDY

The main findings of the study will be divided into the following sections:

- a description of different noise levels and their equation to everyday examples (including examples from the NICU)
 - the actual noise levels measured in the NICU rooms
 - observations made by the researcher of the noise sources in the NICU
 - the vital signs of the infants recorded over the noise level measurement period
 - a description of the degree to which the noise levels in the NICU was a result of direct noise in the NICU or building/NICU acoustics
-

Table I: Noise levels and everyday (and NICU) examples

<u>Intensity level (dBA)</u>	<u>Quality</u>	<u>Example</u>
10	Just audible	Heart beat
20-30	Very quiet	Whisper
40-50	Quiet	Average home Light traffic
60	Moderately loud	Normal conversation Vacuum cleaner
70-90	Loud	Heavy traffic Telephone ringing Pneumatic drill
100	Very loud (uncomfortable)	Power mower
120-140	Painfully loud	Boom box in car Jet plane 30m overhead

Table II: Noise levels in the NICU (Gardner & Goldson, 2002, p.249)

<u>Level dBA)</u>	<u>NICU</u>
+44	Normal nursery
48-69	Humidifiers and nebulizers
50-60	Normal speaking voice
50-73.5 *	Incubator motor noise
53	Median noise level on conventional ventilator
58-85	Noise in NICU (talking, equipment alarms, telephones, radio)
59	Median noise level on high frequency oscillator
59-71*	Using hood of incubator as writing surface
67-72*	Incubator alarm
81-83	Crying of newborns
92.8 *	Opening incubator porthole
84-108	Placing a plastic bottle of formula on top of incubator
96-117 *	Placing a glass bottle of formula on top of incubator
70-116 *	Closing one or both cabinet doors under the incubator
80-124 *	Closing one or both portholes
120	Threshold of pain
120	Dropping the head of the mattress
130-140 *	Banging incubator to stimulate apneic premature infant

* Measured from inside the incubator

1. Noise level measurements in the NICU

The average noise levels in the two rooms (5 & 6) were similar and ranged from 61.0-66.0dBA. This far exceeds the recommended average hourly level of 50dBA for a NICU (Philbin et al., 1999). There were slight differences between the two rooms on both days, because of ventilator and oscillator machinery noise, as well as infant dependent care-giving and nursing activities and difference in staff personalities, some of whom were louder and more boisterous than others.

Percentile levels (L_n) were calculated for the average noise level, minimum and maximum noise levels for both rooms over both days in order to get information of the various levels of noise:

- L_{10} is the level of sound exceeded for 10% of the measurement period
- L_{50} is for 50% of the time
- L_{90} is for 90% of the time

On average, it can be seen that:

	L_{10} (10% of the time)	L_{50} (50% of the time)	L_{90} (90% of the time)
SPL exceeded...	67 dBA	62 dBA	60 dBA
MinL exceeded...	57 dBA	59 dBA	60 dBA
MaxL exceeded...	74 dBA	68 dBA	62 dBA

Most (90%) of the time, the noise levels in the NICU equalled those of normal conversation level or vacuum cleaner (60dBA). For 10% of the time, the maximum noise level exceeded 74dB, which is the equivalent of heavy road traffic noise. The noise levels varied between the rooms and between the days. The NICU is not a static environment and most activities in the NICU rooms vary according to day, number of inpatients, staff and/or parents present and equipment being used. The different NICU sounds contributed to the overall noise levels measured, such as staff conversation, infants crying, removal and adjustment of oxygen feeds and machinery noise

2. Sources of noise observed in the NICU

The researcher was in the NICU while the noise levels were being measured over two 12-hour periods per room on two separate days (8am-8pm over 4 days). During these times she observed and noted everyday NICU activity and events, both unscheduled events (such as new patient admission) and scheduled events (such as infant care procedures, ward rounds, staff handovers).

There were 13 noise event source categories on the checklist and the researcher noted the how often these occurred and recorded them on the checklist. See Table III below:

Table III: *Distribution of noise events observed in the NICU*

<u>Source</u>	<u>Room 1</u> <u>Day 1(%)</u>	<u>Room 1</u> <u>Day 2(%)</u>	<u>Room 2</u> <u>Day 1(%)</u>	<u>Room 2</u> <u>Day 2(%)</u>
Staff conversations	27.8	36.0	33.4	34.1
Bumping stainless cart or apparatus	3.5	2.3	2.7	2.3
Opening or closing trash can lid	7.8	4.0	2.0	3.4
Alarm of monitors	24.3	28.7	23.7	26.1
Care-giving (rubbing, moving or wrapping object) at open incubator	2.6	2.7	1.0	1.1
Multiple sources of noise	5.2	5.3	6.2	5.7
Telephone or pager ringing, intercom broadcasting, radio	7.0	6.3	7.3	8.1
Moving cart, chair and equipment	3.5	2.7	2.7	4.5
Handling equipment of oxygen supply	4.3	0	1.0	1.1
Cleaning apparatus and containers	3.5	2.7	2.7	2.3
Tearing plastic or paper bag	0.9	2.7	5.5	4.5
Bumping or cleaning the incubator	0.9	1.3	2.7	1.1
Others (closing or opening drawers, crying from other infants, staff walking or running, dropping objects, conversations from family)	8.7	5.3	9.1	5.7
<i>Total</i>	<i>100%</i>	<i>100%</i>	<i>100%</i>	<i>100%</i>

The two main noise event sources observed were staff conversation and the alarms of the monitors. Human-related factors e.g. staff conversations, telephone conversations etc, seemed to account for the majority of the noise event sources (65-70% of the noise events

observed). Staff conversations (27.8-36%) were always the largest single contributor to the noise events. The largest single non-human contributor to the noise sources was the alarm noise of the monitors. Additionally, each room had a radio that was placed in the corner of the room. These radios were playing constantly throughout the measurement period, at approximately 68dBA, which was loud enough for the nursing staff to hear over and above the general noise in the NICU.

3. Infants' vital sign responses to noise in the NICU

One of the aims of the study was to attempt to investigate potential relationships between the noise levels in the NICU and infants' physiological responses. Initially, it was necessary to attempt to determine trends in the infants' physiological responses over the two days and between rooms. Only heart rate and respiratory rate were analysed statistically, because these were the only consistent variables monitored in all of the subjects. Oxygen saturation and blood pressure were only measured for 3 of the subjects and it was felt that, due to the already very small sample size (6 subjects), only those variables measured for all infants would be analysed, that is respiratory- and heart rates.

Heart Rate

The results showed that in room 2, the heart rates for the infants remained fairly constant throughout the 12-hour measurement period on the two days the measurements took place. However, in room 1, the infants' heart rates appeared to show a dip during the 2nd and 3rd hours and increased significantly during the 5th hour of measurement (around 12h00-13h00) and then decreased and reached a plateau similar to those found in room 2 from the 6th hour (around 13h00-14h00). No obvious cause could be found for this significant interaction. Nothing "out of the ordinary" occurred in room 1 on either day that did not occur in room 2 over the same period. The daily care-giving routine, ward rounds, X-rays, suctioning, feeding etc occurred routinely in both rooms over both days.

Respiratory Rate

Respiratory rates remained fairly constant over time in each of the two rooms over each of the two 12-hour measurement periods per room.

Correlations of heart- and respiratory rate with noise level

This was done in order to determine if the heart- and respiratory rate were influenced or not by the noise levels measured. It was found that there were no significant relationships between the heart rate and noise levels and the respiratory rate and the noise levels for each of the participants in each room.

4. Building acoustic measurements

Through different measurements, the researcher found that the hospital building acoustics as well as the actual room acoustics were poor. Very few absorbing materials were used in the NICU to try “absorb” the background sounds of the unit and the hospital, such as heating, ventilation and air-conditioning systems, plumbing, communications and through vibration. There were no carpets, acoustic tiles or curtains in either of the two rooms in the NICU, which would have helped improve the acoustic conditions in the unit, thereby indirectly assist in reducing the noise levels.



What do you think should be done to lower the noise levels measured in your NICUs?

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____