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Does loud noise affect the clinical decision-making processes of healthcare professionals in a simulated emergency setting?

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, in partial fulfilment of the requirements for the degree

of

Master of Medicine in Emergency Medicine.

Johannesburg, 2012

DECLARATION

I, Lindy-Lee Folscher, declare that this research report is my own work. It is being submitted for the degree of Master of Medicine (Emergency Medicine) in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

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_____

DEDICATION

This work is dedicated to all healthcare professionals who unselfishly sacrifice themselves in order to provide their fellow man with the highest quality of care.

PUBLICATIONS ARISING FROM THIS STUDY

Poster presentation at the Emergency Medicine Conference 2011 in Cape Town, South Africa.

ABSTRACT

Introduction: Healthcare professionals working in the Emergency Medicine field are often required to function in difficult environments. Noise is one environmental factor that may adversely affect their performance.

Objectives: To firstly determine if there is any difference in cognitive task performance required for clinical decision-making of healthcare professionals in a quiet compared to a noisy environment and secondly, to assess the subjective experience of participants with regards to performance in a noisy environment.

Design: Prospective cross-over study.

Setting: Three Academic Hospitals in Johannesburg.

Participants: Forty one doctors exposed to emergency management of patients.

Methods: A 30 minute examination consisting of six matched and pre-validated questions was conducted. Half of the questions were completed with exposure to ambient noise (range 40-45dB(A)) and the other half with exposure to pre-recorded background Emergency Department noise at 80-85dB(A). The questions were completed in alternating quiet and noise. Each question was scored out of 10 and the time taken to complete each question was recorded.

Main Results: Overall mean test scores in quiet and noise were 18.7/30 and 19.4/30 ($p=0.36$) respectively, with overall time for test completion of 836s in quiet and 797s ($p=0.005$) in noise. While there was no statistically significant difference in task performance, 65% of the doctors found the noise distracting with 88% experiencing varying degrees of stress.

Conclusions: This study showed no difference in cognitive performance in a quiet compared to a noisy environment. Deterioration in functionality might be seen with higher levels of noise and/or longer exposure.

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NOMENCLATURE

Abbreviations

AAP	American Academy of Paediatrics
bpm	Beats per minute/ breaths per minute
CCU	Cardiac care unit
CHSE	Centre for Health Science Education
CI	Confidence interval
dB	Decibels
dB(A)	Average decibels
ECG	Electrocardiogram
ED	Emergency Department
EP	Emergency Physician
EPA	Environmental Protection Agency
FIFA	Fédération Internationale de Football Association
hr	Hour
Hz	Hertz
ICU	Intensive care unit
IQ range	Interquartile range
ISO	International Standards Organisation
IV	Intravenous
JCAHO	Joint Commission on Accreditation of Health Care Organisations
LAeq	Equivalent continuous level
LAeq,T	Average equivalent level over a time period
LAmax	Maximum sound pressure level

N	Number
NICU	Neonatal intensive care unit
OHSA	Occupational Health and Safety Act
OSCE	Objective Structured Clinical Evaluation
Q	Question
REM	Rapid eye movement
RTS	Revised trauma score
s	Seconds
SD	Standard deviation
SEL	A weighted sound pressure level
STEMI	ST segment elevation myocardial infarction
T	Time
USA	United States of America
WHO	World Health Organisation

Definitions

Baseline sound pressure level	Background noise level, expressed in dB
Decibels	Unit of measurement of sound loudness
Equivalent continuous level	Average noise level over a set time period
Maximum sound pressure level	Sound with maximum intensity expressed in dB
SEL	The total amount of energy in a particular sound event

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PREFACE

Healthcare professionals often work in difficult circumstances while fulfilling their clinical duties. Examples of these difficult circumstances include: long shift hours, poor resources, lack of adequate facilities, inadequate staffing, and high noise levels. During the 2010 FIFA Soccer World Cup healthcare professionals were exposed to high noise levels during their duties at the various stadia. It was during this work that the question arose as to the possible detrimental effects of noise exposure. Apart from personal discomfort created by high noise levels, the question arose as to whether loud noise would be detrimental to the functioning of healthcare professionals required to treat patients in such environments. It then became apparent that it is not only at special events that healthcare professionals are exposed to loud noise, but also during everyday activities in the Emergency Departments, theatres, intensive care units etc. While hospital noise levels are not likely to rise as high as those achieved in stadia during a soccer game, literature has demonstrated significant noise levels in most areas of hospitals, with the Emergency Department, theatre and intensive care units being particularly noisy (1, 2).

I therefore sought to assess whether high noise levels would have a detrimental effect on the cognitive functioning of healthcare professionals. I also realised that high noise levels contributed significantly to fatigue during work in noisy areas, and therefore also sought to assess whether others had the same experience. This study revealed both surprising and interesting results.

Chapter 1 **INTRODUCTION**

1.1 Motivation and rationale for this research

In the field of Emergency Medicine, healthcare professionals are exposed to a variety of environments in which they may be required to resuscitate a patient. Resuscitation of a patient requires rapid integration of various data sets and rapid decision-making processes which requires concentration, attention, mental efficacy, the use of short-term and working memory and problem-solving ability. Decisions are often “life and death”, which in and of themselves places strain on the mental capabilities of the professional. The environments in which healthcare professionals find themselves are often far from ideal, and yet these individuals are expected to function optimally. One example of such an environment is at a soccer match. There was much publicity during the FIFA 2010 Soccer World Cup hosted in South Africa as to the adverse effects of the vuvuzela (plastic air-horn that makes a loud noise) on hearing, with researchers measuring sound outputs of between 113 and 131dB(A) from a single vuvuzela (3). This far exceeds the 85dB(A) limit for occupational exposure by the Occupational Health and Safety Act (OHSA) (4). It was during work in this environment that the question arose as to whether healthcare professionals are able to think clearly enough in order to adequately resuscitate a patient under such adverse noise conditions. Apart from a noisy environment outside of the hospital at such events, studies have demonstrated that the Emergency Department is one of the noisiest places within the hospital, yet this is the place where critically ill patients need to be managed with speed and precision (2, 5). Noise levels recorded in the Emergency Department during the examination and treatment of children was on average

84.2dB with averages of 95.4dB(A) being recorded during procedures (6). Tijunelis *et al (7)* measured the noise levels in an Emergency Department over a period of eight hours and found an average of 52.9dB(A) with peak levels of 94–117dB occurring every minute. The Emergency Department is also a stressful environment to work in, given the nature of the work. It is therefore important to assess the effect of loud noise on the ability of healthcare workers to solve clinical problems in a simulated emergency setting.

1.2 Statement of the problem

From current literature we know that noise exposure has positive and negative outcomes, with negative effects being seen with more complex tasks (8). The question remains as to the acute effects of loud noise exposure on cognitive performance of healthcare professionals, when given problem-solving tasks relevant to the resuscitation environment. The subjective experience of healthcare professionals required to function in a noisy environment is also unknown.

1.3 Aim and objectives

1.3.1 Study aim

The aim of this study was to assess the subjective and objective effect of loud noise on cognitive functioning of healthcare professionals in a simulated emergency setting.

1.3.2 Study objectives

1. To determine if there was any difference in cognitive task performance required for clinical decision-making of healthcare professionals in a quiet compared to a noisy environment.

2. To assess the subjective experience of participants required to perform in a noisy environment.

1.4 Ethics

This research was approved by the Human Research Ethics Committee of the Faculty of Health Sciences of the University of the Witwatersrand (protocol approval number M110564 - see Appendix 1). Written informed consent was obtained from all participants enrolled in the study.

Chapter 2 **LITERATURE REVIEW**

2.1 Introduction

2.1.1 Noise definitions

Sound is a sensory perception that is evoked by physiological processes in the auditory region of the brain to the sound pressure waves that enter the ear from the external environment (4). Noise is defined by the World Health Organisation (WHO) as unwanted sound (4). Other definitions include: any sound that serves as an obnoxious stimulus for people causing subjective annoyance and irritation; any sound that is undesirable or without musical quality; sound without value; “the wrong sound in the wrong place at the wrong time”; a sound varying randomly and aperiodically in intensity and frequency; audible acoustic energy that adversely affects the physiological or psychological well-being of people (4, 9, 10). Noise has also being classified as the most ubiquitous pollutant and a pathogen (9).

2.1.2 Noise measurements

Sound is measured by measuring the sound pressure levels of the air vibrations that make up sound (4). The human ear is able to detect a very wide range of pressure levels therefore a logarithmic scale is used, therefore a 1dB increase in sound measured equates to a tenfold increase in loudness (11). Sound is generated by alternating compressions and expansion of air and is propagated through air creating vibrations during its passage (12). These vibrations are measured in terms of number of vibrations per second i.e. frequency, which is measured in Hertz (Hz) (4). The frequency of the sound determines the pitch of the sound, with high pitched sounds being squeaky in nature and low pitched sounds being humming in nature (12). The human ear is able to hear a broad

range of frequencies ranging from 20-20 000 Hz (4). The frequencies that the human ear is sensitive to are called A-weighted sound pressure levels (SEL) and is expressed as dB(A) (12). Sound pressure levels vary with time therefore measurements of noise fluctuations need to be integrated over a time interval. The time interval of integration may be either fast or slow. A fast response time corresponds with a time constant of 0.125s which closely matches the integration of the human hearing system. Therefore, when measuring sound the fast response time should be measured (4). When measuring a combination of noise events over time the LAeq,T is used. The LAeq,T is useful to measure continuing sounds. If one wants to measure the maximum level of individual noise events then LAmax is used. Discrete noise events can also be assessed by their SEL. The SEL readings of a noise event may be more useful since they are derived from the complete history of the noise event rather than a single maximum value (4).

2.2 Noise sources and examples of loudness

Modern society is characterised by rising environmental noise levels due to an increase in motorised traffic, preferences for noisy leisure and recreational activities and an increase in urbanisation with the resultant “megacities” (12). Noise levels are best understood when compared to commonly known sound events (11). Examples of loudness from various noise sources include: whisper in a quiet library 30dB(A); normal conversation 60-70dB(A); city traffic (inside the car) 85dB(A); truck traffic 90dB(A); power saw 110dB(A); rock concert 115dB(A); gun blast 140dB(A) and loudest sound possible 194dB(A) (4).

2.3 Adverse effects of noise

Noise has various effects on human functioning, many of which have been found to be detrimental, especially when humans are exposed to high levels of noise. Noise exposure has been shown to have an effect on communication, hearing, sleep, mental state, task performance, cardiovascular function, annoyance levels and social behaviour (4, 13). Cognitive performance is impaired by noise (4) but most studies have looked at the effects of chronic noise exposure. These studies have been performed to evaluate the effect of chronic noise exposure on various aspects of human functioning and physiology (4, 8, 13-15). Many of these effects may also be demonstrated following noise exposure in the acute setting.

2.3.1 Noise-induced hearing impairment

The International Standards Organisation (ISO) 1999 defines hearing impairment as “a disadvantage imposed by a hearing impairment sufficiently severe to affect one’s personal efficiency in the activities of daily living, usually expressed in terms of understanding conversational speech in low levels of background noise” (12). There are various causes of hearing impairment namely: aging, ototoxic drugs, some industrial chemicals, head injuries, certain disease states, hereditary factors and environmental noise exposure (12). Noise induced hearing impairment is defined as an increase in the threshold of hearing due to noise exposure (4). Death of hearing tissue occurs with acute unprotected exposure to sound levels above 180dB(A) but since most individuals are unlikely to ever be exposed to such levels it is the chronic lower level noise that poses the greatest threat (4). Chronic exposure to continuous noise, for example in industrial settings, over 85dB(A) results in progressive hearing loss (13). In general noise-induced hearing loss does not occur at eight hour exposures of less than 75dB(A) or 24 hour

exposures of less than 70dB(A). Impulse noises in excess of 80dB(A) result in a temporary threshold shift which in turn predisposes the individual to impulse noise-induced hearing loss (12). Impairment generally occurs at higher frequency ranges of 3000-6000Hz with the largest effect seen at 4000Hz (4). It is estimated by the WHO that 120 million people worldwide are affected by noise-induced hearing impairment making it the most prevalent irreversible occupational hazard (4). Animal studies have demonstrated that children are more susceptible than adults to noise-induced hearing loss (12). The most direct consequence of hearing impairment is the effect of speech comprehension creating communication difficulties which may lead to severe social handicap (4, 13). This may be particularly relevant to healthcare workers who are frequently exposed to high noise levels e.g. orthopaedic operating theatres and the Emergency Department (ED) (2, 5).

2.3.2 Non-auditory effects of noise

2.3.2.1 Sleep disturbance

Many industrial workers, exposed to prolonged chronic noise, complain of insomnia and disturbed sleep (16). Continuous sound levels exceeding 30dB and single noise events exceeding 45dB(A) have been shown to interfere with sleep quality due to difficulty in falling asleep, repeated awakenings with alterations of sleep stages or depth, increased blood pressure, vasoconstriction, changes in respiration, cardiac arrhythmia, and increased body movements (4, 13). Studies have revealed that prolonged daytime noise exposure results in a decrease in rapid eye movement (REM) sleep and shortened sleep cycles which in turn results in mood changes, concentration difficulties and irritability. This is because REM sleep is essential for the

modulation of mood and the maintenance of attention during wakefulness (16). The result of sleep disturbance is impairment in overall functioning through reduced perceived sleep quality, increased fatigue, depressed mood or well-being all resulting in decreased performance (4). Older people have been shown to be more vulnerable to the disruptive effects of noise on sleep quality (9). However, studies on sleep disturbance have demonstrated that adaptation and habituation do occur, as demonstrated by the fact that city dwellers are able to sleep through street traffic noise but are awakened by the background cricket noise when away in the countryside (12).

2.3.2.2 Speech communication

The frequency range for speech is 100–6000Hz with the sound pressure level of normal speech at about 50dB. Interference of speech by noise occurs via a masking process in which speech discrimination and perception become difficult resulting in communication impairment (4). The masking effect of noise is obviously more pronounced in individuals suffering from hearing impairment. Difficulties in speech comprehension as a result of noise interference is associated with problems in concentration, fatigue, uncertainty and low self-confidence, irritation, misunderstandings, reductions in work capacity, difficulties with human relations and numerous stress reactions (4).

2.3.2.3 Cardiovascular effects

Noise exposure activates the neuroendocrine system as evidenced by higher levels of urinary catecholamine excretion (12). This adrenergic activation causes some short-term physiological changes, namely increased blood pressure, heart rate and peripheral vasoconstriction with consequent

increased peripheral vascular resistance (4, 13). Noise levels greater than 70dB(A) have demonstrated statistically significant blood pressure elevations in adult participants (12). Cardiovascular effects of noise exposure have also been demonstrated in children resulting in higher systolic and diastolic blood pressure levels as well as an increase in resting adrenaline and noradrenaline levels (12). While studies suggest that there is a weak association between long-term environmental noise exposure and the development of hypertension, no dose-response relationship has yet been established (4). Early evidence also suggests an association between long term noise exposure at levels of 65-70dB and increased risk of ischaemic heart disease (4).

2.3.2.4 Mental health effects

Studies have demonstrated that noise caused significant psychological stress on participants who were performing cognitively demanding tasks in a noisy environment as the noise led to higher perceived levels of exertion and mental strain (17). While noise has not been linked to mental illness directly, it has been demonstrated that the annoyance response to noise results in feelings of fear, mild anger and a belief that one is being unavoidably harmed which may accelerate and intensify the development of mental disorders (4). Environmental noise exposure has been shown to elicit a variety of symptoms including anxiety, emotional stress, nervous complaints, nausea, headaches, instability, argumentativeness, sexual impotency, changes in mood, along with general psychiatric symptoms of neurosis and hysteria (4). People with mental health problems are more prone to experiencing the negative effects of noise (18).

2.3.2.5 Endocrine response

The ear has been classified as the “sentinel of the senses” and serves a basic arousal function (9). Noise is a non-specific stressor (16), that, with sudden occurrence, results in a startle response which in turn activates the reticular activating system producing a stress reaction (9). The stress reaction elicits a neuroendocrine response that is characterised by a release of adrenaline and noradrenaline from the adrenal medulla. Adrenergic stimulation results in blinking, muscle flexions, peripheral vasoconstriction, increased heart rate, galvanic skin response, hyperreflexia, slowed gastrointestinal motility and a reduction in gastric and salivary gland secretions. Significant increases in the vasoconstrictor angiotensinogen II have also been demonstrated following exposure to noise. Bharathan *et al*. (18) describe how noise levels above 55-60dB are capable of triggering both acute and chronic elevations in catecholamine and cortisol levels. Anxious individuals have demonstrated an exaggerated startle response as evidenced by large increases in plasma and urinary hydroxycorticosteroid levels. The duration of the neuroendocrine response typically lasts for 1-2 hours following noise exposure (9).

2.3.2.6 Noise annoyance

Noise has the ability to cause annoyance in humans. Noise annoyance is defined as “…a feeling of resentment, displeasure, discomfort, dissatisfaction or offense when noise interferes with someone’s thoughts, feelings or actual activities” (12). Noise annoyance generally increases with increasing levels of noise and age (19). Studies performed on office workers revealed that constant sound levels in excess of 55dB(A) were associated with higher annoyance with 35-40% of office workers reporting feeling highly annoyed by

levels from 55-60dB(A) (12). Similar studies performed on industrial workers revealed similar levels of annoyance when sound levels rose above 85dB(A) (12).

Other determinants of noise annoyance include attitudes to the noise with noise experienced as more disturbing if deemed unnecessary; perceptions of control over the noise with rapidly changing, unpredictable noise-producing negative effects; the trait of noise sensitivity; hearing status and task demands (12, 20, 21). The study by Kjellberg *et al*. (22) of 439 office workers demonstrated that annoyance was found to be related to sound levels and the self-related "necessity" of the noise, with participants being more distracted and annoyed by noise that they felt they had no control over and that was unpredictable in nature.

While individuals vary in their ability to cope with annoying noise, coping and adaptation to the noise results in a decrease in the level of annoyance (23). This has been demonstrated in individuals working in noisy places e.g. Intensive Care Unit (ICU) staff, who after some time report minimal or no disturbance owing to the environmental noise (24). The coping mechanisms instituted by individuals to counteract the effects of noise requires extra effort on the part of the individual, with this extra effort being likely to contribute to fatigue (21). Therefore annoyance resulting from noise results in a reduction in efficiency (10). Different noise characteristics cause different levels of annoyance in individuals (23). Noise annoyance has been shown to be significantly related to auditory and mental fatigue. Auditory fatigue is characterised by sound sensitivity, hearing fatigue and tinnitus. Mental fatigue

is defined as tiredness, headaches, concentration difficulties and irritation (25). Following studies on the subjective experience of subjects on cognitive task performance during noise exposure, Ljungberg *et al*. (26) concluded that while performance did not decrease during noise exposure, subjects consistently rated memory tasks to be more difficult along with higher annoyance ratings.

Chronic noise exposure is also associated with annoyance with numerous studies demonstrating this link. Air traffic noise has been found to be the most disturbing with road traffic noise coming in second place and railway noise being least disturbing (12).

2.3.2.7 Social and behavioural effects

Noise levels above 80dB have been shown to increase annoyance and irritability, reduce helping behaviour, and increase aggression in individuals predisposed to aggressiveness (13). In order to cope with noisy environments, humans have demonstrated distancing behaviours in which they become less interpersonally engaged, less caring and less reflective (9).

In one study investigating stress reactions on cognitively demanding tasks in office noise it was found that there was minimal physical stress displayed by subjects but significant self-reported emotional distress when working in the noisy environment (17). In the Breier *et al*. (27) study which investigated the stress effect of loud noise at 100dB(A) on healthy volunteers, the volunteers reported higher self-ratings of helplessness, lack of control, tension, stress, unhappiness, anxiety and depression following the noise exposure. The

sense of helplessness and powerlessness that is described following prolonged noise exposure may become generalised, resulting in “learned helplessness” (9). Studies performed on industrial workers suggest that exposure to sound levels greater than 75-90dB(A) is associated with higher accident rates and higher absenteeism rates (12).

2.3.2.8 Performance effects

The auditory nerve is involved in providing activating impulses to the brain helping regulate vigilance and wakefulness that is necessary for optimal performance. Therefore some sound stimulation is necessary for optimal functioning and a completely silent world may be harmful as a result of sensory deprivation. Therefore, both too much and too little noise can be harmful (4). This fact accounts for the mixed results that have been found by studies evaluating the effect of noise on cognitive performance. While studies have demonstrated significant impairment in sustained attention at 100dB, others have demonstrated improvements in performance thereby supporting the theory that noise stimulation increases arousal by which an increase in performance is observed, but only up to the point that overarousal occurs after which decrements in performance are observed (8). In study by Loewen and Suedfeld (28) on 45 undergraduate volunteers, it was found that individuals completed complex tasks better in quiet but felt more aroused and performed better when exposed to masked noise on simple cognitive tasks.

Noise also acts as a distracting stimulus which may have a disruptive effect (4). Factors affecting performance during noise exposure are personality, attitude towards the task, task type and noise characteristics (29, 30).

Personality

Individuals who score high on scales for introversion demonstrate greater reactions to noise and overarousal during performance. While introverts are able to maintain speed and accuracy during noise exposure, it is at the cost of greatly increased mental effort. In contrast to this, extroverts display less annoyance and a better ability to concentrate in a noisy environment (29). Thus the concept of work efficiency emerges which is defined as the ratio of objective results to the subjective cost of adaptation to noise. The subjective cost of maintaining performance in noise is lowest for noise tolerant subjects who will therefore generate greater work efficiency (30).

Attitude towards task

Evidence suggests that task performance during noise exposure is dependent on motivation rather than fatigue (31). Stave (31) conducted a study on the effects of the cockpit environment, which is characterised by exposure to both noise and vibration, on pilot performance and demonstrated the following:

- Despite the onset of fatigue, performance of the required tasks did not degrade.
- Performance actually improved with time. This improvement was attributed to the fact that pilots were able to meet the demands of the tasks by an increase in personal effort.
- The increased effort was only demonstrated by subjects motivated to succeed at the given task.
- While highly motivated subjects were able to maintain/improve performance under stress, as fatigue built up, it resulted in a reduction in motivation with a consequent degradation in performance (31).

Task type

Research has revealed that noise effects are different for different types of tasks i.e. psychomotor tasks are less affected by noise than higher order cognitive processes with negative effects more likely with more complex tasks (8).

Numerous studies evaluating the effect of chronic noise exposure on cognitive performance have demonstrated impairment in cognition affecting reading comprehension, long-term memory and motivation, with tasks involved in central processing and language comprehension being most affected by noise exposure (15). A study done on children in a classroom environment demonstrated that even at moderate levels (50dB(A)) of noise, disruptions occur especially where a wide range of information needs to be taken in, assessed, recalled and/or work needs to be done under pressure (14). This particular study also noted that decision-making times were extended, the amount of information processed was reduced and error rates increased (14). This is relevant to the emergency setting where healthcare workers are required to assimilate a lot of information and rapidly make decisions. Therefore, it needs to be established whether noise has the same impact on adult subjects. In another study investigating the effects of noise on mental performance, it was noted that monotonous, simple routine tasks were not impaired by noise under 95dB(A) but where complex tasks were performed, adverse effects were seen from sound levels of 70-80dB(A) (15).

A study done on the effect of operating theatre noise on anaesthesia residents during the induction of anaesthesia demonstrated a deterioration of

mental efficacy and short-term memory (10). Noise levels in this setting were recorded at 77.32dB(A) (10).

Noise characteristics

Low frequency noises are defined as, "…broadband noise with the dominant content of frequencies from 10 to 250 Hz" (32). Examples of low frequency noise include noise generated by ventilation systems, heating systems, air-conditioning systems, pumps, compressors, diesel engines, gas turbines and power stations. Low frequency noise is annoying and has an effect on performance especially tasks that demand perceptiveness and concentration (32). Pawlaczyk-Luszczynska *et al*. (32) found that subjects who were categorised as being highly sensitive to low frequency noise demonstrated worse performance in tasks requiring continuous attention when exposed to that frequency at a level of 50dB(A). Persson Wayne *et al*. (33) also demonstrated this in their study showing that low frequency noise at moderate levels contributed to a decrease in work capacity. These findings are, however, not restricted to low frequency noises. Ryherd and Wang (34) described how higher frequency sounds were also associated with a higher level of discomfort, annoyance and lower performance.

Most studies on the effect of dB level on performance demonstrated impairment in performance after exposures to noise levels between 90 and 100dB(A). This is especially evident with tasks that require sustained attention (8). In the Gomes *et al*. (35) study investigating the effects of prolonged workplace exposure to loud noise above 90dB(A) on aircraft technicians, it was found that more intense, prolonged noise had a more serious implication for performance degradation. Broadbent (36)

demonstrated that exposure to loud noise stress (greater than 95dB(A)) improved reaction times on well-rehearsed or simple tasks but found impairment on more complex tasks, especially where subjects perceived themselves as having no control over the noise.

Conversely, it has also been noted that prolonged exposure to the same noise may result in habituation following which the negative effects on performance may then disappear. It would appear that individuals perform better when the acute noise exposure matches their normal exposure. Individuals who are regularly exposed to certain noise levels will actually demonstrate poorer performance in quiet environments when compared to those accustomed to quiet environments (15).

Most studies have found intermittent noise to be more distracting than continuous noise, with negative effects being the greatest for unpredictable, rapidly-changing noise (8, 15). The studies by Becker *et al. (37)* and Stave (31) investigating cognitive performance during exposure to continuous aircraft noise at levels ranging from 85dB to 100dB revealed no degradation in performance even after prolonged exposure. There were, however, increased perceived levels of fatigue and workload reported by subjects.

2.3.2.9 Subjective noise sensitivity

Individuals display varying levels of sensitivity to noise (30). Studies investigating the relationship between noise exposure, subjective noise sensitivity and cognitive performance have been inconsistent with their findings. However, most have found that noise-sensitive subjects performed

poorer on cognitive tasks during noise exposure (38). A study exposing 202 office workers to white noise ranging from 45-110dB found that the subjective experience of the noise had a more significant effect on performance than the actual noise level (39). In support of the psycho-physiological theory of arousal, studies have found that subjective noise sensitivity affects performance, with noise-sensitive subjects demonstrating poorer performance in noise on tasks requiring near maximal concentration. It is postulated that when strained to near maximal levels these individuals have little spare mental capacity to cope with the noise (30). The subjective perceived loudness of the noise contributes to perceived annoyance and distraction and is significantly related to task performance scores (34). It has been demonstrated that noise annoyance generally increases with increasing sound levels, however, individuals with an intrinsic sensitivity to noise may demonstrate annoyance at several levels of objective noise while those with a lower intrinsic sensitivity may experience annoyance only at high levels of noise (40). Noise sensitivity also seems to correlate well with the individual's need for privacy, with private individuals being more affected (9).

2.3.2.10 Summary of noise stress effects on task performance

Studies have shown various effects on mental performance during noise exposure. Listed below is a summary of the effects of noise stress on task performance:

1. Noise exposure has both positive and negative outcomes on task performance with negative outcomes less likely in initial stages of exposure (41).

2. Negative effects on performance are more likely to be seen with complex tasks (8).
3. When improvement in performance is demonstrated, it is more likely to occur with simple tasks since these simple tasks are likely to elicit boredom therefore noise acts as a stimulus to increase arousal and attention (41).
4. Noise at low-moderate levels of steady noise (<95dB) is less likely to affect performance when compared to intermittent noise or noise at higher levels (8).
5. Effects on memory have been demonstrated early on in task performance at noise levels as low as 70-80dB (14).
6. Verbal and reading comprehension is negatively affected by noise (42).
7. Noise results in attentional selectivity in which attention is tunnelled towards central features of a task, thereby bringing relevant stimuli into sharper focus. This may be associated with a loss in perseverance in addressing complex tasks therefore resulting in the tendency to find simple solutions to complex problems (9).
8. Noise stress results in a reduction in individual's confidence in his/her ability to perform a task (41).
9. Noise stress results in activation of the performer often to levels that exceed optimal for the specific task, which results in an increased rate of work but also an increase in the frequency of errors (43).

10. Noise produces more pronounced effects on performance when individuals are experiencing sensory overload and are working at near capacity levels (9).
11. Loud, uncontrollable and unpredictable noise has the most significant impact on performance (14, 44).

2.4 Guidelines and recommendations for noise exposure

Noise limits for noise exposure have been set by various bodies among which are the ISO, OHSA and WHO. Both peak sound levels and continuous sound levels should be limited. For adults, peak sound pressure levels should not exceed levels greater than 140dB(A) and no more than 120dB(A) for children in order to prevent noise-induced hearing loss. This discrepancy between adult and child exposure levels is due to the fact that children are more sensitive to noise induced hearing loss (4). Occupational exposure should not exceed 85dB(A) over eight hours. When exposed to environments where elevated sound levels are unavoidable (e.g. entertainment events and ceremonies), WHO recommends that individuals should not be exposed to levels greater than 100dB for longer than four hours on more than four occasions per year and that the peak levels should always be below 110dB (4). These guidelines are published with the prevention of noise induced hearing loss in mind and any sound pressure levels higher than these recommendations require some form of hearing protection (4).

2.5 Hospital sound environment

The hospital environment should facilitate patient recovery and safety while promoting employee health and productivity. It is an environment in which life and death decisions are made and should be one that ensures rapid thinking, effective

communication, good patient care and restfulness for patients (45). This is, however, not the case due to rising noise levels (25). Noise levels in hospitals are unacceptably high. This is a problem inherent to every major hospital despite the fact that regulatory bodies have published guidelines regarding the recommended noise levels (46). In the 1940s and 1950s the hospital environment was similar to that of a quiet library reading room, with signs posted on the walls that read “Quiet please” and signs surrounding the hospital area reading “Hospital zone- Quiet” (9). This, however, has changed significantly. With the advancement of technology, there has been a steady rise in noise levels since the 1960s. Daytime LAeq levels measured in 1960 were 57dB(A) but 72dB(A) in 2005. Night-time levels have also increased from 42dB(A)to 60dB(A) (46). This translates to increase of 0.38dB per year during the daytime and 0.42dB per year during night-time hours (5). Modern hospital noise trends have average day-time sound levels of 50-70dB(A) and night-time levels of 67dB(A), which is ten times greater than the recommended levels (8). The noisiest time periods are typically early morning and late afternoon, with the staff members being found to be the chief noise makers (9). These high noise levels have repeatedly been described as a source of dissatisfaction for patients, staff and visitors (47).

2.5.1 Sources of hospital noise

The mere process of treating and delivering care to patients generates noise therefore some noise is necessary and unavoidable (39). Hospital noise is characterised by irregularly occurring sound events that are generated by mechanical and human sources and propagated by structural design (25). Mechanical noise sources include equipment alarms, carts delivering food or

supplies, industrial floor cleaners, ventilation systems, heating systems, banging of doors, and mechanical surgical equipment (45). Human noise sources include staff conversations and discussions, footsteps, overhead paging systems and noise from other patients (25). Structural design aspects that enhance the reverberation of sound include sound reflective tile and ceiling surfaces, stainless steel tables and equipment, rooms with large open spaces and unit layout (9, 48). Of these noise sources, Overman Dube *et al.* (39) found staff voices, carts, traffic, cardiac monitor alarms and overhead paging systems to be the most disturbing for patients. Table 2.1 shows some examples of noise levels generated by various sources within the hospital.

Table 2- 1 Examples of hospital noise and the sound levels generated in average decibels.

Noise source	Sound level dB(A)	Reference
IV infusion pump	44-80	50
Staff making beds	56-66	50
Ringing telephone	68	24
Conversations among staff	74	24
Vacuum cleaner	74	24
Cardiac monitor alarm	75	50
Anaesthetic machine alarm	84	51
Trolley sides being lowered	85	50
Suctioning	85.5	51
Opening gloves	86	9
CO_2 laser	87.9	52
Footsteps	89	24
Shouts from staff	90	9
Objects falling on the floor	94.5	51
Stryker® saw	105.1	52
Connection of gas supply	106	51
Dropping steel bowels	108	9
Oxygen hose disconnection	123	52

2.5.2 Recommendations for hospital noise levels

The WHO (2) guidelines for hospital noise state that continuous background noise in the wards should not exceed 30dB(A) with maximum night-time peaks of 45dB(A). Further recommendations state that continuous sound pressure levels should not exceed 35dB(A) in patient's rooms, which includes all areas where patients are being treated (4). The Environmental Protection Agency (EPA) recommends that continuous noise levels should not exceed 45dB(A) during the day and 35dB(A) at night (49). The American Academy of Paediatrics (AAP) recommends that the hourly noise levels should be kept below 45dB(A), and that sound level should not exceed 50dB(A) for more than 10% of the time, with peaks never exceeding 65dB(A) (50). The International Noise Council suggests that noise levels in areas where patients receive acute care should not exceed 45dB(A) during the day, and 20dB(A) at night (9).

2.5.3 Noise levels in hospitals

Noise levels in various hospitals have repeatedly been shown to be excessive and above the levels recommended by all regulatory bodies. These excessive noise levels are a common stressor and a serious health hazard and have been considered to be a pollutant of the hospital environment (49). Therefore in order to assess the problem of excessive hospital noise many authors have described and measured the noise levels within different areas of various hospitals. These measurements display many similarities and to a certain extent are likely to be representative of many different hospitals.

2.5.3.1 Noise levels in the wards

Noise measurements at Johns Hopkins Hospital in the children's ward, oncology ward, and adult medical and surgical wards found an average sound level of 50-60dB(A) across these areas. The noisiest areas were the corridors, nurses' stations and occupied patient rooms, which demonstrated relatively constant sound levels (51). Tsara *et al.* (52) measured sound levels in the pulmonology ward at two Greek hospitals and found average sound levels of 36.4-69.7dB(A), with the lowest levels being recorded at night. The highest peak sound levels (95.3dB) in an acute surgical ward in Nottingham UK have been described as exceeding those measured at a busy supermarket (82.5dB), coffee shop (83.4dB), and hospital main entrance (83.4dB) (53). The source of these peak noises were slamming bins, trolleys, and monitoring equipment alarms (55).

2.5.3.2 Noise levels in the Intensive Care Unit (ICU)

The noise level in the ICU is often excessive due to the extended staff involvement in patient care and the routine use of mechanical sound-generating equipment. Sound levels measured in the ICU environment are generally around 60-70dB(A) with increases up to 80-90dB(A) frequently being demonstrated (24). In addition to mechanical noise, Akansel and Kaymakci (24) found the source of ICU noise to be generated by humans 47.34% of the time. A study investigating ICU noise, found that talking was the largest contributor to the peak sounds measured with mean peaks of 84.6dB occurring 26% of the time (54). Recorded sound levels in an ICU

in Turkey ranged from 49dB(A) to 89dB(A) with an average of 64dB(A) (24). Measurements in a Greek hospital ICU were on average between 54.7-65.6dB(A) (52). Peak sound levels recorded in an Australian adult general ICU reached 90.89dB(A) (55). Noise recordings in a neurosurgical ICU found that 90% of measured peaks exceeded 70dB(A) (45).

2.5.3.3 Noise levels in the operating theatre

Surgery has been demonstrated to be a noisy business! Kracht *et al*. (51) conducted sound measurements in 38 operating theatres at Johns Hopkins Hospital and found average levels of between 55-70dB(A) with significant peaks during surgical procedures. These sound peaks were in the range of 90-105dB(A) with peaks in the neurosurgical and orthopaedic theatres exceeding 100dB(A) 40% of the time. The greatest contributor to orthopaedic theatre noise was the mechanical equipment used during procedures with bone saw peaks reaching 120dB(A) (51). Sound recordings in a Greek hospital's operating theatres measured minimum levels of 46.7dB(A) and maximum levels of 106dB(A) (56).

2.5.3.4 Noise levels in the ED

Measured noise levels at a teaching hospital in New York showed the ED to be the noisiest place in the hospital with average levels of 68.3dB(A) followed in second place by the ICU with average levels of 64.1dB(A) (18). Noise levels were higher on weekdays (69.5dB(A)) than on weekends (67.2dB(A)) owing to greater patient volumes during the week (18). Similar findings were reported at Johns Hopkins Hospital with the noise levels in

the adult ED being 5-10dB(A) higher than other areas of the hospital, at an average of 60-70dB(A) (2). In this study, the triage area at the entrance of the unit was found to be the noisiest with recorded levels of 65-73dB(A). Measurements were particularly high in the speech frequency band, which is to be expected given the heavy reliance of verbal communication in the ED setting (2). Average noise levels recorded at four EDs in Phoenix was 69.7dB(A), which is comparable to levels measured at a level 1 Trauma Centre in Chicago where the mean level at the nurses' station was 57.60dB(A) with peaks of 70dB(A) and the mean level in the trauma room was 56.32dB(A) with peaks of 81dB(A) (57). Tijunelis *et al.* (7), following an investigation of noise in a large inner city Los Angeles ED, found average sound levels of 52.9dB with peaks of 94-117dB(A) occurring every minute. Some sources of these peak levels included alarms on monitors 87dB(A), phones 90dB(A), yelling for ECG technician or medications 90dB(A), conversations between staff 90-93dB(A), laughing of staff 94dB(A), slamming of cabinets 91dB(A) and garbage can closing 100dB(A)(7). Vinodhkumaradithyaa *et al*. (5) measured maximum sound levels in the ED at 82.40dB(A) which was second in loudness only to the surgical operating theatre where levels of 84.10dB(A) were measured. Suggestions as to the factors contributing to high noise levels in this setting included high patient turnover, overcrowding, communication between healthcare professionals, conversations by visitors, crying babies, screaming children, emotional outbursts and equipment usage (5).

2.5.4 Effects of hospital noise

Noise has both psychological and physiological effects on humans, many of which are negative; therefore the hospital auditory environment often demonstrates negative health effects on both patients and staff (45).

2.5.4.1 Effect on patients

Noise levels that peak at 70dB(A) have been shown to disturb 50% of healthy subjects, but when patients are under stress or are seriously ill or injured the degree of the reaction to noise is suggested to be greater (24). Questionnaires have revealed that 50% of patients complain about hospital noise (9), with patients identifying noise as one of the most severe stressors experienced during their hospital stay (58). Besides this described annoyance, it has been demonstrated that noise is detrimental to patients healing (49). Noise levels below 40dB(A) are required to facilitate good rest and sleep (24). ICU noise has been shown to result in frequent patient arousals and consequent sleep fragmentation which leads to sleep deprivation (54). Besides the obvious negative effects of sleep deprivation on mood, alertness and performance, it also results in delayed recuperation (46). Sudden, unexpected noise results in the startle response with consequent cardiovascular arousal (resulting in elevations in blood pressure, heart rate and respiratory rate). Impulse noise that is 30dB above the background noise will elicit a startle response (9). Noise exposure has also been linked to extended hospital stay and increased requirements for pain medication (45). These noise effects become more apparent with exposure to noise levels greater than 70dB(A) (24). Animal

studies have revealed delayed wound healing following noise exposure (45). Environmental noise has also been implicated in the development of the so-called “ICU syndrome” in which patients exhibit symptoms of distress, bewilderment and hallucinations, and report feelings of extreme instability, vulnerability and fear (46). Frail, elderly patients have been found to be more vulnerable to noise pollution (18).

Neonates are also more vulnerable to noise pollution. Effects of noise on neonates include autonomic changes with impulse noise; alterations in endocrine and metabolic functions resulting in decreased growth hormone levels; increased corticosteroid levels and increased adrenaline levels with consequent increased oxygen consumption and decreased growth; alterations in physiological stability with tachycardia, bradycardia, apnoea, blood pressure changes, and decreased oxygen saturation; hearing loss due to the combination of ototoxic medication with loud noise exposure; and sleep deprivation which disrupts growth and development (50).

Patients with greater noise sensitivity suffer more hospital-induced stress (24). In Akansel and Kaymakci’s (24) survey of 35 ICU patients, 60% graded unexpected noise to be the most disturbing type of noise. Noise sources that were most disturbing were noises from other patients, patients admitted from the ED or operating theatre, monitor alarms, conversations among the staff and vacuum cleaner noise (24).

Patients are also at risk for noise-induced hearing loss from hospital noise exposure. This is especially true for patients taking ototoxic medication (e.g. aminoglycoside antibiotics), who when exposed to noise at or above 58dB(A) may develop hearing deficits (59).

2.5.4.2 Effects on staff

The effect of noise on hospital staff includes speech interference, increased medical errors, disrupted concentration, reduced short-term memory, decreased mental efficiency, increased fatigue, stress and burnout, decreased ability to distinguish critical physiological functions such as heart and lung sounds and, in extreme cases, noise-induced hearing loss (25, 45).

A study by Persson Wayne *et al*. (25) on the ICU environment found that 91% of staff perceived noise as having a negative impact on the work environment with 43% stating that they were disturbed by the noise and a further 44% reporting noise annoyance. The noise annoyance was significantly higher in the ICU staff when compared to primary healthcare workers (21.8%) and office staff (20.1%). In this study the most annoying sounds were generated by medical equipment, followed by conversations between staff members and corridor activity (25). These findings were supported by a similar study that found that noise was perceived by hospital staff as a negative environmental factor, with 61% of respondents reporting being “very annoyed” by the usual noise levels in the hospital. The major noise sources identified by these staff members were derived

from visitors, patients and other staff members (60). Excessive noise and the resultant annoyance has been shown to result in a decreased sense of “psychological well-being” leading to a reduction in productivity and increased human errors in office settings (11). These findings are also relevant in the hospital setting.

Comfortable speech communication between two people occurs at 50-55dB(A) (54). The background noise in hospitals often exceeds these levels suggesting that staff members are frequently required to raise their voices in order to be heard and understood. When background noise is greater than 85-90dB, people have to shout to be heard (61). This has obvious implications for speech communication and intelligibility, medical errors and patient privacy (45). In addition to these implications, the requirement by staff to frequently raise their voices results in increased levels of fatigue (2).

The sudden, unexpected sounds in the hospital environment also elicit the startle reaction described in patients. This startle reaction results in elevations of blood pressure, heart rate and stress (49). These physiological arousal reactions and the resultant energy mobilisation, if prolonged, result in a reduction in the regenerative capacity of the body with a resultant increased risk of illness (62). A study evaluating the effect of the paediatric ICU noise environment on nurses’ heart rates found that for every 10dB(A) increase in the average sound level, the nurses’ average heart rates increased by six beats per minute. It was also found,

however, that there was less heart rate variability in nurses with greater number of years working in the ICU, suggesting some adaptation to the environment (58).

Noise has been identified as a cause of workplace stress with a correlation demonstrated between increased noise levels and a higher frequency of headaches, noise-induced stress and burnout symptoms amongst ICU nurses (63). This is especially true after prolonged exposure e.g. working an eight hour shift. It has also been found that nurses self-reports of noise-induced stress correlates with self-reported emotional exhaustion (62). The study by Morrison *et al.* (60) demonstrated that for every 10dB(A) increase in sound level, there was a 27 point increase in stress ratings and a 30 point increase in annoyance ratings. A survey of physicians and residents in a paediatric ED found that high noise levels were perceived as stressful, resulting in irritability and feelings of helplessness (64).

The noise levels experienced by staff at a hospital do not typically raise concern for noise-induced hearing loss by most people. However, various studies have revealed that aspects within the hospital soundscape place staff at risk for noise-induced hearing loss. A study measuring the sound levels generated by children during examination and procedures in the ED recorded average levels of 76.4dB(A) during examination and 95.3dB(A) during procedures with an overall average of 84.2dB(A). In addition to this, four patients generated noise in excess of 108dB. The authors of this study argue that exposure to such noise levels warrant precautions

against noise-induced hearing loss for staff members, since exposure to sound levels in excess of 100dB(A) for as little as 15 minutes per day may lead to noise-induced hearing loss (6). Another high risk environment for noise-induced hearing loss is the operating theatre where sound peaks in excess of 110dB(A) and sometimes 120dB(A) are not uncommon. A study found that half of the orthopaedic surgeons assessed had noise-induced hearing loss (65).

2.6 Job stress in Emergency Medicine

The field of Emergency Medicine is a unique speciality due to the intensity of the stressors placed on individuals working in this environment (66). The practice of Emergency Medicine in the USA has been described as one that is characterised by burnout and job dissatisfaction, resulting in high rates of physician turnover and relatively short careers in the field (67). In order to understand job stress in this setting, it is important to explore contributory factors.

2.6.1 Stress and burnout

Stress is defined as a normal, non-specific physical, psychological and physiological response of the body to any demand that is placed on it (67). Stressors are classified as external or internal. External stressors result from environmental or psychosocial factors, whereas, internal stressors originate within the individual and may be physiological or cognitive (67). Stress may have an effect on cognition, especially when exposure is prolonged, affecting perception, memory, knowledge, problem-solving and decision-making (67).

When demands are made on our physical and mental energy that are excessive and beyond our coping ability, it leads to the first stage of a chronic process leading to burnout (68). Burnout is defined as, “a haemorrhaging of oneself and depletion of energy in which personal resources seem to be at an end, leaving individuals helpless and negative” (69). Factors contributing to burnout include loss or perceived loss of control, verbal or physical aggression from patients, lack of support and overcommitted/dedicated personality types (68). The “burnout syndrome” is characterised by a triad of emotional exhaustion, depersonalisation and a low sense of personal achievement (70). Work-related emotional exhaustion is defined as being overextended and exhausted by one’s work (67). Features of emotional exhaustion include negative self-concepts, negative job attitudes and a loss of concern and feelings for patients (71). Depersonalisation is “an unfeeling and impersonal response towards recipients of one’s service, care, treatment or instruction” (67). Burnout has been linked to personal dysfunction as evidenced by physical exhaustion, insomnia, substance abuse, marital discord and job attrition (70).

Individuals reporting the highest levels of emotional exhaustion and burnout symptoms are those with poor coping mechanisms (66). In contrast, individuals with positive coping strategies report far higher levels of job satisfaction. Factors associated with positive coping include being able to draw from experience, seeing humour in taxing situations, involvement in non-work activities, choosing not to worry, routine exercise, more holiday time, involvement in research, and increased age (66, 67, 71).

2.6.2 Sources of stress in the ED

There are numerous factors within the ED that act as a source of workplace stress. These factors can be divided into patient-related factors, personal factors and environmental factors.

Patient-related factors adding to the stress of the ED include:

- The types of patients presenting to the ED
- Social cases where policies are vague
- Aggressive patients and families
- Increased risk of workplace violence
- Large case variability and exposure to infectious agents (62, 72, 73).

Personal factors include:

- Shift work
- Feeling of a lack of control
- Critical decision-making based on incomplete information
- High demands with low decision latitude combined with poor social support from superiors and workmates
- Conflict with management
- Feelings of uselessness as a result of the lack of psychological reward of having cured a patient as the focus is on rapid stabilisation
- Self-criticism
- Lack of sleep
- Deficient financial rewards
- Lack of personal time
- Litigation concerns

- A lack of self-esteem as a result of a faulty and unfounded hierarchy that places Emergency Medicine specialists at the “bottom of the food chain” (62, 70, 72).

Environmental factors include:

- Bright lights
- Loud noise
- Hard tile floors
- Lack of air or poor air circulation
- Lack of food services afterhours
- Deficiencies in teamwork
- Lack of communication
- Insufficient staffing
- High patient volumes and overcrowding
- Limited resources
- Work-time pressure
- Unfair expectations that doctors are “superhuman” (7, 70, 72).

2.6.3 Rates of burnout for Emergency Physicians (EPs)

In the early years of the speciality of Emergency Medicine, over 50% of EPs reported medium to high levels of emotional exhaustion which was attributed to the pace of work within the ED as well as the frequent need to deal with crisis situations (66). Seventy eight percent of the respondents in one study reported strong feelings of depersonalisation when dealing with patients (66). Studies in the USA have suggested that the average professional life of an EPs is four years (72). A further study found that while the vast majority of EPs

reported normal stress levels, a disproportionate number reported high levels of stress and depression with 45% planning on leaving the speciality of Emergency Medicine in the following 10 years (72). The average percentage given for doctors having a higher than normal stress level is 28%, compared to 18% for the normal population (72). A study of Romanian EPs found that 37.8% experienced emotional exhaustion, which is a key manifestation of burnout (72). Goldberg *et al*. (70) demonstrated that 60% of EPs studied reported high to moderate levels of burnout. This study sample also demonstrated significantly higher degrees of emotional exhaustion and depersonalisation when compared to other medical professionals and the general population. They also displayed a significantly lower sense of personal accomplishment (70). A survey of Canadian EPs, found that 35.1% were dissatisfied with their lives (67). A study of 192 doctors working in EDs in Turkey revealed that 15% had depressive symptomatology, with a further 14.6% reporting high anxiety scores (73). Fields *et al*. (71) conducted a study on burnout amongst physicians working in paediatric critical care and found that 50% were burnt out or at risk for burnout. Another study done in the USA concluded that while attrition rates for board certified EPs was lower than had previously been estimated, attention still needed to be paid to the factors linked to burnout and attrition in order to increase staff retention and improve job satisfaction (74).

2.6.4 Noise as a stressor

High noise levels are an external environmental stressor but may also act as an internal cognitive stressor causing mental fatigue (75). Noise is a major stressor in

modern industrialised society (37). Noise has been classified as one of the most common occupational hazards in the modern era despite the legislative pressures to regulate noise exposure (16). Loud noise is a significant stressor able to elicit physiological, psychosocial and behavioural responses in both humans and animals (16). Studies on the effects of noise on factory workers have found noise to be associated with job dissatisfaction, irritability, fatigue and employee illnesses and injuries. This described distraction and stress due to noise is not unique to the factory environment and has frequently been described in the hospital environment (58).

Topf (40) describes hospital noise pollution in terms of an environmental stress model. Stress is subjective and the impact of stress on the individual depends on coping. Effective coping results in a decrease in the stress response. The stress response has three phases namely: alarm reaction, resistance and adaptation and exhaustion and illness. If positive coping occurs, the individual will adapt and develop resistance. If, however, coping mechanisms are poor, illness and exhaustion will develop with prolonged exposure to the stressor. As noted previously, hospital sounds are ambient stressors. Noise has also been shown to elicit a potentially negative subjective response.

According to the stress model, personal factors act as ambient stress risk or resistance factors. Examples of personal factors include:

- Intrinsic noise sensitivity
- Personality predisposition (individuals with a greater need for social acceptance complain less about noise)
- Restricted capacity for coping

- Personal and cultural preferences
- Life stage and age, with adolescents tolerating higher sound levels
- Sex, with women demonstrating more reaction to sounds than men
- Perceived social support
- The addition of other ambient stressors (44).

According to the environmental stress model, subjective ambient stress results in negative health outcomes. A study of 100 ICU nurses found a positive correlation between self-report scores for noise-induced subjective stress and the frequency of headaches on the job as well as links to emotional exhaustion (40).

2.6.5 Noise and fatigue

Fatigue is “an inability or unwillingness to continue effective performance” (76). Hospital environmental noise is a contributing factor to fatigue and it is highly likely that noise, together with other stimuli and job demands, places an increased load on staff members with resultant overall tiredness (25). Other causes of fatigue are excessive workload, stress, sleep loss and circadian rhythm disruption (76). Fatigue results in a deterioration of cognitive function which leads to impaired learning and thought processes, memory deficits, interpersonal function and an increased incidence of errors. These errors may be minor in the beginning, but as performance further decreases the resultant mistakes can have disastrous consequences for patient care (76).

2.7 Noise management

2.7.1 Motivation for noise reduction in hospitals

As far back as 1859, the hazard of excessive noise on both staff and patients was identified by Florence Nightingale who stated, "…unnecessary noise, or noise that creates expectation in the mind, is that which hurts the patient. Unnecessary noise, then, is the most cruel absence of care which can be inflicted either on sick or well" (59). Noise pollution has been demonstrated to be detrimental to patients' healing and makes errors more probable while contributing to healthcare provider fatigue and burnout, therefore noise control has been identified by numerous researchers as a urgent priority (7, 49). Grumet (9) sums up the problem of hospital noise very effectively in the following statement, "The hospital, designed as a place of healing and tranquility for patients and of scholarly exchanges among physicians, has become a place of beeping, buzzing, banging, clanging and shouting – staff members scurry around in an urgent and hurried manner, talk loudly and tersely, and speedily scribble notes on charts as they rush headlong from one duty to the next… Call bells go unanswered, social engagement declines, and simple courtesies are omitted as the staff struggles to cope with the sensory and work overloads."

2.7.2 Noise management

In order to address the problem of noise pollution in the hospital environment, there needs to be collaboration among various role players namely: acoustics, building systems, engineering and architecture, nursing, management and environmental and occupational medicine (45). In the WHO "*Guidelines for community noise*", a model for the policy process for community noise management is given (4). This model provides a useful framework in order to

address the problem of noise pollution. The model comprises six stages for the development and implementation of the policy (4).

1. *Agenda setting – Noise problem identification*
2. *Problem analysis – Noise impact assessment*
3. *Policy formulation – Noise control options*
4. *Policy adoption – Decision on noise regulation*
5. *Implementation – Operation of noise regulation*
6. *Policy evaluation – Evaluation of noise regulation*

Numerous studies have identified the problem of hospital noise pollution and have presented clear evidence as to the need for noise reduction within the hospital environment. A few authors have designed and implemented noise-reducing strategies with varying degrees of success (49,53,57). It is important to recognise the problem of noise pollution and design strategies relevant to the particular setting and to remember that since sound measurement is according to a logarithmic scale, any small reduction in the sound level may have a significant impact on overall sound effects (54). Therefore, when looking at ways to address noise levels, one does not have to try to make drastic or expensive changes immediately. While some noise sources are uncontrollable, the majority are modifiable, requiring simple steps which will go a long way in making a difference (49).

In a study on noise levels in an urban hospital, 92% of interviewees felt that noise reduction was possible by general improvement of working conditions, control of noise at the source, better acoustic insulation and staff and visitor education to reduce unnecessary noisy behaviours (60). Overman Dube *et al.*

(39) instituted a noise reduction intervention across 57 patient care units in two hospitals and found that simple strategies such as using soft voices, closing doors, dimming lights and limiting overhead paging had a small but significant effect in decreasing mean noise ratings by both staff and patients.

2.7.3 Noise-reducing strategies for the hospital environment

The main contributors to hospital noise are equipment-related, human-related and related to area design. While equipment and area design-related noise may be harder to modify, noise related to human behaviour is modifiable and has already be shown to contribute to greater than 50% of measured noise levels (54). Table 2-2 describes strategies that can be implemented to reduce noise in the hospital setting.

Table 2- 2 Strategies aimed at noise reduction in the hospital setting.

Interventional Category	Intervention	Support from the literature
Unit redesign for acoustical improvement	Acoustically absorptive walls, doors and ceiling tiles and insulation for quieter ventilation/air conditioning systems	Remodelling a burn acute care ward saw a reduction in sound levels from 88dB to 55-58dB(A) (45). Remodelling the treatment area in a cancer unit resulted in a 5dB(A) reduction in sound levels (45).
	Overhead banners and soft seating for sound absorption Modifying the unit layout so that sources of noise are away from the patient	A Primary Healthcare centre was designed to create an environment that is psychologically soothing for patients and staff. Recorded noise levels were 53dB(A), which were lower than levels in similar settings. The authors believe that they were successful in reducing noise with design adaptations (11,48).
	Single patient rooms rather than open design	Redesign of a neonatal ICU unit from standard open plan design to a single-family room design resulted in a reduction in sound levels and improved staff perceptions with regards to workplace quality (77, 78).
	Relocating the nurse's station	Nurses conversations are often the source of most of the noise (48)
	Placing noisy equipment away from patient's head	(59)
	Decreasing the number of beds per unit and increasing the space between beds	(48)

Equipment modification	Reducing the volume of machine alarms Purchasing equipment with the quietest alarm/adjustable alarm	Studies conducted using experienced ICU staff revealed that they were only able to identify critical alarms 50% of the time and non-critical alarms 40% of the time thereby concluding that too many alarms are used, many of which are difficult to discern anyway, therefore only adding to noise pollution (48,49) Another study on machine alarms during anaesthesia demonstrated that 78% of alarms were spurious, with only 3% indicating actual risk to the patient (79).
	Using plastic drawers instead of metal	(48)
	Muffling wheels on carts/trolleys	(18)
	Wireless communication to replace overhead paging	Webb (80) demonstrated that in a University Hospital, the use of pocket pagers reduced the daily overhead paging from 5000 to 800.
	Switching mobile phones onto vibrate mode	(5)
	Providing hearing protection to staff and patients for excessively noisy procedures	An extracorporeal shock wave lithotripter exposes the patient to 112dB(A) and the operator to 110dB(A) (59)
Addressing Human Factors	Moving teaching rounds away from the bedside and limiting conversations around the bedside	A study on modification of a NICU for noise reduction revealed that structural changes alone were not enough to reduce sound levels in the unit therefore concluding that a combined approach is essential (48).
	Staff education about noise and training doctors and nurses to speak softly	Evidence suggests that some staff members adapt to noise and become unaware of the noise they are making due to desensitization therefore retraining is needed (59)
	Visiting regulation and enforced quiet time	A study on enforced quiet time showed that a quiet time intervention resulted in lower noise levels in the ward during the specified time, in which sleep was more likely amongst patients (80).
	Soft soles shoes for staff	(81)
	Encouraging patients to use headphones for TV and radio	(59)

When viewing the noise reduction strategies suggested in Table 2-2, it is easy to see the importance of good leadership in the whole process. In order for a given strategy to be successful, hospital management needs to support the concept of noise reduction thereby setting it as a priority, allocating funds for reduction strategies and assisting in staff education (47). Noise reduction is everyone's responsibility and duty, and as Tsiou *et al.* (56) propose, "… workers in the field need to be made aware of and be sensitive to the issue (of noise). Awareness means this: if the door squeaks- oil it, if the telephone rings loudly – lower the volume, if the trolley's wheelbase is broken- have it replaced, don't leave inhalers,

respiratory or other equipment switched on unnecessarily, when you speak- do not shout and keep your voice lower still at night."

2.7.4 Benefits of noise reduction

Researchers have implemented noise reduction strategies in various areas in the hospital and have demonstrated the following benefits after intervention:

2.7.4.1 Benefits for patients

- Improved sleep (45)
- Reduced cardiovascular arousals (45)
- Decreased incidence of re-hospitalisation (45)
- Reduced stress (11)

2.7.4.2 Benefits for staff

- Improved speech intelligibility (62)
- Improved staff psychosocial environment (45)
- Reduction in job stress (7)
- Reduction in fatigue (49)
- Reduction in provider burnout rates (7)
- Potential reduction in physician errors (7, 62)
- Reduction in conflicts due to staff feeling more relaxed with lower levels of irritability (62)
- Enhanced staff productivity (11)

2.8 Summary of the literature review

Noise generation is the consequence of our modern lifestyle and is at times excessive (12). High noise levels are found in many different environments which includes hospitals. Hospitals should be quiet environments yet sound levels found within many areas of a hospital are unacceptably high, reaching sound levels similar to those of busy supermarkets (55). Noise exposure has the potential to have negative effects on hearing, sleep quality, communication, cardiovascular functioning, healing, mental and emotional wellbeing, and mental performance (4, 46). Effects on mental performance are variable and are influenced by the personality of the individual, individual motivation, task type, the noise level and duration of exposure, with deterioration in complex task performance seen following prolonged exposure to unpredictable noise at moderate to high levels (29-32). In addition to this, noise is an environmental stressor capable of evoking high levels of annoyance as well as contributing to fatigue and burnout (12, 76). For these reasons, noise is a serious environmental factor that may affect both the performance and well-being of healthcare professionals, and therefore needs to be addressed (51).

Chapter 3 **MATERIALS AND METHODS**

3.1 Study design

Prospective cross-over study.

3.2 Validation study

The OSCE test used in the study was validated beforehand by administration to 24 subjects. Sample size estimation based on dependent samples with:

- Significance level of 0.05
- Standard deviation of the difference between the two tests of 10
- Power of 0.8
- A difference in means of 5
- Rho of 0.75 to ensure adequate pairing of questions.

This validation study was conducted using 24 doctors working at three different hospitals, namely, Helen Joseph Hospital Emergency Department, Chris Hani Baragwanath Hospital Emergency Department and the Paediatric Department Rahima Moosa Hospital.

3.3 Study setting and population

The study was conducted using 41 doctors in three different venues namely, Centre for Health Sciences Education (CHSE) conference room, Chris Hani Baragwanath Hospital; Doctors' Tea Room, ICU Chris Hani Baragwanath Hospital; Seminar Room, Paediatric Department Rahima Moosa Hospital. The participants were recruited after responding to an advertisement sent via email or from interest via word of mouth. Only one person refused entry into the study. Each individual

formed both the exposed and unexposed subject for the particular test as their individual performance was compared under the two different exposure conditions.

Inclusion criteria:

All participants were healthcare professionals with exposure to the resuscitation environment who had volunteered and consented to participate in the study, with no self-reported hearing impairment.

Exclusion criteria:

1. Individuals receiving psychopharmacological therapy who had had a recent change (in the preceding six weeks) in their treatment regimen that may have altered their mental performance e.g. anti-depressants, anti-epileptics, sedatives and mood stabilisers.
2. Individuals on any ototoxic medication.
3. Alcohol consumption in the previous 12 hours.
4. Individuals who were post call i.e. having worked a night shift the previous night.

3.4 Study Protocol

3.4.1 Noise exposure

Participants were exposed to pre-recorded Emergency Department noise at a level of 85dB(A)LAeq for 15 minutes (three x five minute segments) during the test administration. The pre-recorded noise consisted of background noise from a busy ED and some pertinent distracting noise e.g. shouting, sirens etc. The noise was played over a sound system with surround sound capabilities

with an amplifier to ensure uniform sound distribution throughout the room, and maintained at the prescribed level by monitoring the level on a Quest 210 sound level meter. The ambient ("quiet") noise level of all three venues was similar i.e. ranging from 40–52dB(A) and never exceeding 52dB(A) in any of the venues.

3.4.2 Outcome measures

3.4.2.1 OSCE exam

An OSCE exam was set up in three different venues in order to accommodate the participants. The OSCE exam consisted of 6 testing questions with three sets of matched questions (questions 1 and 4; 2 and 5; and 3 and 6) so that each participant answered a similar question in a quiet and noisy environment. Each question was scored out of 10 and the total time taken to complete each question was recorded. The maximum time possible for each question was five minutes (300 seconds). Questions 1 and 4 required ECG interpretation, questions 2 and 5 required drug dosage calculation and questions 3 and 6 required clinical data interpretation (see appendix 2).

3.4.2.2 Subjective experience

Following the OSCE test, a questionnaire was administered to evaluate the participants' daily work environment and their subjective experience during the testing session. Questions were asked in four categories- demographic; symptoms experienced during the noise exposure; perceived impact of noise on performance and additional comments on

the experience. Demographic questions included age, job description, years of experience, hearing function, perceived noise level in work environment and subjective noise sensitivity. Sound levels within the work environment were rated on a five point graded scale:

- Very quiet
- Quiet
- Occasionally noisy
- Noisy
- Excessively noisy

The individual's disturbance by their workplace noise level was also assessed using a five-point rating scale:

- Not at all
- Slightly
- Moderately
- Very
- Extremely.

Subjective noise sensitivity was rated on a four point graded scale:

- Not at all
- Somewhat
- Rather
- Very sensitive

The next section on symptoms experienced during the noise exposure had participants rate the following symptoms on a five point graded scale of not at all, somewhat, rather, very and extremely:

- Tiredness

- Lack of concentration
- Headache
- Irritation
- Confusion
- Being out of control
- Pressure
- Physical distress

Participants who selected “rather” and “somewhat” were considered to have experienced mild symptoms and were thus grouped together, while those who selected “very” and “extremely” were considered to have experienced severe symptoms and were grouped together.

The third section comprised questions with regard to the perceived impact of the noise on performance by asking if the noise made each of the task categories more difficult. This was rated on a five point graded scale. The final section of the questionnaire was an open-ended question requesting additional comments on the OSCE testing experience (see appendix 3).

3.4.3 Data collection

Data on test performance was collected by the researcher following marking of the tests according to a memorandum to avoid any bias in the marking and scoring of the tests. The information was recorded on a data collection sheet.

The following steps were followed:

1. Participants were numerated in order for test results to remain anonymous.
2. Participants were split up between the questions so that half of the participants completed even questions in quiet and odd questions in noise, while the other half completed even questions in noise and odd questions in quiet.
3. Participants were allocated a question to start at.
4. Participants received written instructions and answer sheets with their corresponding number on the top.
5. Participants were requested to complete each question as fast and as accurately as possible and to inform the time keeper when they were done.
6. After completion of each question the participant then recorded the time taken for that question on the bottom of the answer sheet.
7. If the participant ran out of time and did not complete the question, a time of five minutes was allocated to the question.
8. Each test question was performed with exposure to pre-recorded noise at a level never exceeding 85dB LAeq alternating with ambient “quiet” noise.
9. The noise level was monitored using a Quest 210 sound level meter.
10. After the testing session, participants were requested to fill in a questionnaire that evaluated their subjective experience of the noise exposure and opinion of their performance.

11. The above-mentioned process was repeated over four testing sessions in order to accommodate 41 participants.
12. The tests were marked and scored by the researcher and the results were then entered on a data collection sheet.

3.4.4 Sample Size Estimation

This study made use of 41 healthcare professionals. The sample size required for the study was calculated at 36 participants. The parameters used in determining the sample size were:

- Significance level of 0.05
- Standard deviation of the difference between the two tests of 10
- Power of 0.8
- A difference in means of 5
- Rho of 0.75

Forty two participants were enrolled into the study, 18 for each test condition (noise and quiet, although the whole group was exposed to both environments) and six extra to make provision for participants electing to withdraw from the study at any point for whatever reason, thereby ensuring that the goal sample size of 36 participants was reached. One participant withdrew halfway through the study due to pressing clinical duties. Therefore, a total of 41 participants participated in the study.

3.4.5 Data Analysis

The data analysis had two components i.e. descriptive and inferential. The aggregate score, of each individual was compared between the noise and

quiet settings. The performance of the individual questions was compared between the groups that completed each question in quiet compared to those who completed it in noise. Performance was assessed according to total test score (out of 30), total question score (out of 10), time taken for question completion (with maximum time of 300 seconds), time for task completion (with a maximum time of 900 seconds) and pass/fail rate (a pass mark of six out of ten was allocated). The speed with which participants completed the respective questions was broken into three categories namely 1-800 seconds, 801-859 seconds and 860-900 seconds and the average score of participants falling into these categories was compared. Participants were also grouped according to years of experience for analysis of performance according to experience. A cut off of six years was chosen in order to separate interns and junior medical officers/registrars from senior registrars/consultants. Descriptive analysis made use of frequency tables for variables namely: participant's work experience, test score, time for question completion, and pass/fail rate. Cross tabulation was used to compare work experience with various test results. Graphs and tables were compiled displaying the relationship of the different variables.

Non-parametric analysis was performed to make provision for the fact that due to the small sample size as well as time limit for test completion some of the data was not normally distributed, therefore the tests of significance used were the Wilcoxon matched pairs test for paired data comparing results during quiet and noise exposure and the Mann-Whitney test for unpaired data comparing

the performance of different categories of participants during quiet and noise exposure. The Chi-square and McNemar were also used.

3.4.6 Significance level

A p <0.05 was considered to be significant for all statistical tests. For convenience, all very small p values were represented as p<0.0001, rather than for example p=0.000005.

3.5 Software

All data was entered and stored in a Microsoft Excel® (Microsoft Office 2010, Microsoft Corporation) spreadsheet. All analysis was conducted using StatSoft, Inc. (2008) STATISTICA® (data analysis software system), version 10.www.statsoft.com.

Chapter 4 **RESULTS**

4.1 Validation study results

Twenty four doctors participated in the validation study in order to determine whether the questions to be used in the OSCE test were adequately paired. Based on the findings from the validation study, some questions were assessed as being too long for the allotted five minutes, and were therefore shortened in order to ensure possible completion in the allotted time for the final test used in the study.

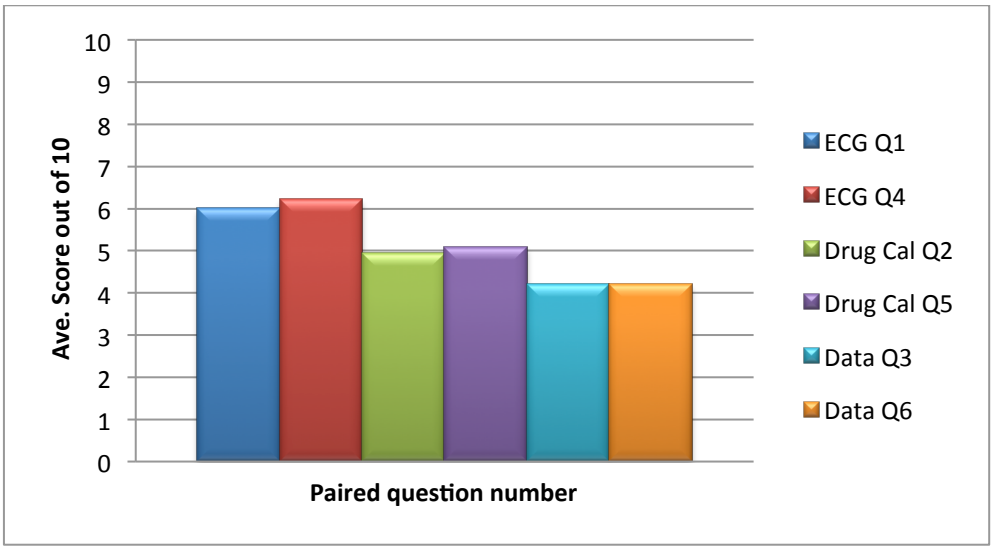

Figure 4- 1 Comparison of performance on three sets of tests by 24 participants during the validation study.

Figure 4-1 demonstrated that test score performances on the paired questions were similar, with no statistical difference in scores when the Wilcoxon matched pairs test was applied (see Table 4-1).

Table 4- 1 Significance level of validation study results.

Question	First question		Second question		p value
	Median	IQ range	Median	IQ range	
ECG Q1 & 4	6.0	4-8	6.0	5-7	**0.31**
Drug calculation Q 2 & 5	5.0	4-6	5.0	3-7	**0.64**
Data interpretation Q 3 & 6	4.0	2-6	4.0	3-6	**>0.99**

Questions were scored out of 10. Significance was determined using the Wilcoxon matched pairs test.

4.2 Job titles and work noise parameters of participants

The 41 participants recruited for participation were doctors, with varying degrees of clinical experience, and included interns, medical officers, registrars and consultants. The proportion from each category can be seen in Table 4-2.

Table 4- 2 Percentage of participants by job title.

Job title	N	%
Consultant	11	26.8
Registrar	19	46.3
Medical Officer	6	14.6
Intern	5	12.2

Note: due to rounding off the total percentages add up to 99.9%.

Subjective noise sensitivity was assessed by individuals rating how sensitive they felt they were to noise. Participants, who stated that they were “rather” or “very” sensitive to noise, were regarded as demonstrating high subjective noise sensitivity.

Table 4- 3 Subjective noise sensitivity of participants.

Noise sensitivity	N	%	
Not at all	2	4.9	Low noise sensitivity
Somewhat	22	53.7	
Rather	12	29.3	High noise sensitivity
Very	5	12.2	

Table 4-3 shows that less than half of the participants (41.5%) were thus categorised as having a high noise sensitivity.

The participants’ work environment was assessed for perceived noise level by means of a five-point rating scale.

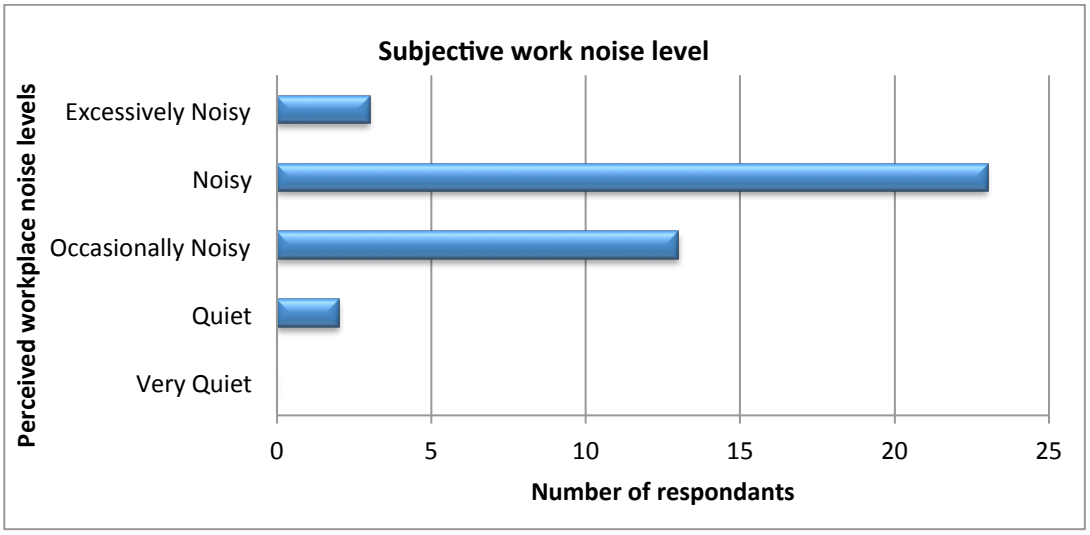

Figure 4- 2 Assessment of perceived noise levels in current work environment by participants.

Figure 4-2 demonstrates that 63% of participants felt that their work environment was noisy or excessively noisy, with less than five percent describing their work environment as quiet.

The individual's disturbance by their workplace noise level was also assessed using a five-point rating scale (Figure 4-3).

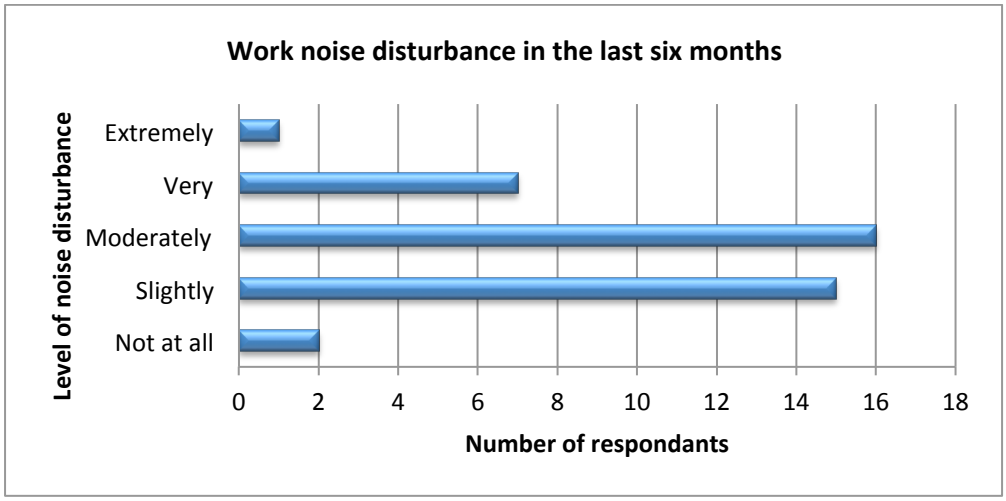

Figure 4- 3 Level of disturbance of participants by workplace noise in the preceding six months.

As seen in Figure 4-3, almost one in five participants (19.5%) reported significant disturbance by their workplace noise, with an additional 39% reporting moderate disturbance from their workplace noise.

4.3 OSCE test results

4.3.1 Comparison of overall performance in quiet compared to noise

The Wilcoxon matched pairs test was used to compare the average score (out of 30) for all the questions completed in quiet compared to those questions completed in noise; and the median time (in seconds) taken to complete all the questions under quiet conditions compared to the median time taken during the noise exposure.

Table 4- 4 Comparison of overall performance of participants in quiet compared to noise for test score and time for question completion

	Quiet		Noise		P value
	Median	IQ range	Median	IQ range	
Overall test score	18.5	14-23	20.0	14.5-22	0.2
Overall time taken	863	780-900	819	730-869	0.006

The total test score possible was 30 and the maximum time possible was 900 seconds for all questions completed in quiet and noise respectively. The p value was calculated using the Wilcoxon matched pairs test.

As seen in Table 4-4, the higher overall test score achieved by participants on questions performed during noise exposure was not significant. There was, however, a significant difference in the overall time taken for question completion with faster times achieved during noise exposure.

4.3.2 Comparison of question performance in quiet compared to noise

The average score (out of 10) and average time taken (in seconds) of those participants completing a particular question in quiet was compared to that of the participants who completed the question in noise. The Mann-Whitney test was applied to these results in order to assess statistical significance of the difference.

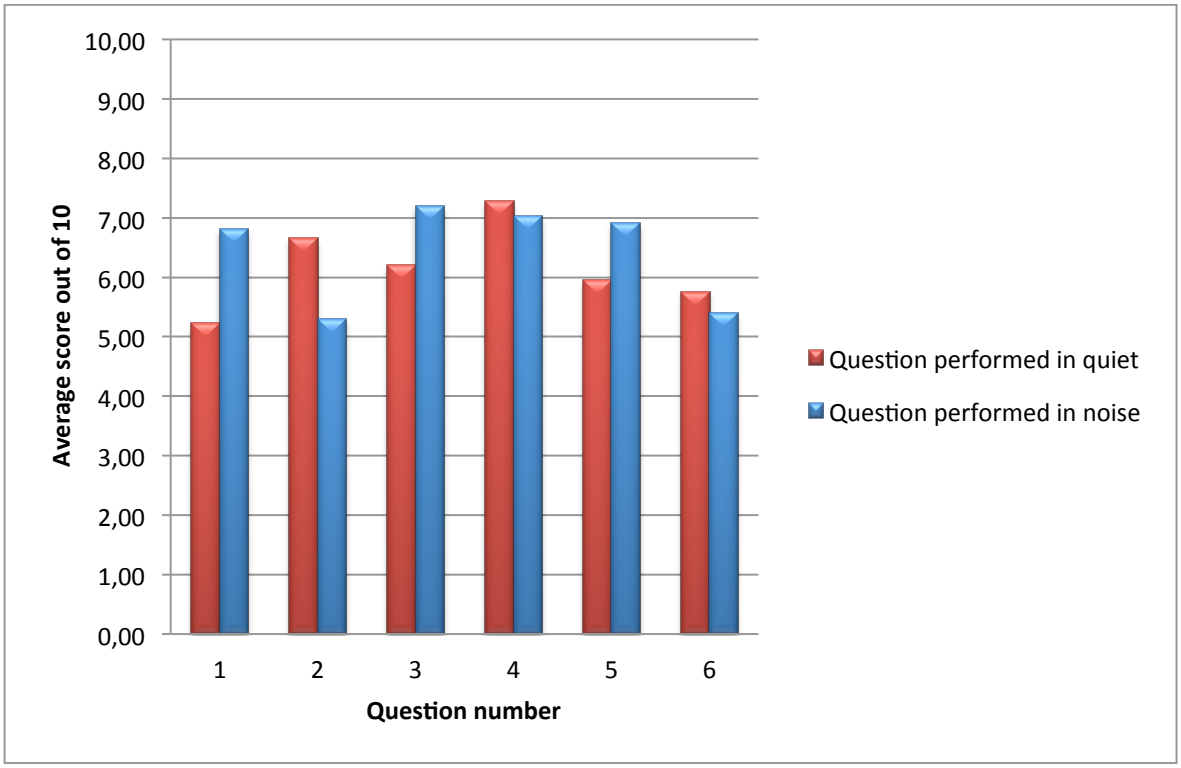

Figure 4- 4 Average test score (out of 10) in participants completing a particular question in quiet compared to those completing the same question in noise.

The average scores achieved for most of the questions during quiet and noise exposure were within one point of each other. The exception to this was the first question for which the average score was 1.8 points better in the noise.

Table 4- 5 A comparison of question performance: median score achieved during quiet and noise exposure.

Question	Quiet		Noise		p value
	Median	IQ Range	Median	IQ Range	
Question 1	5.0	4.5-6	7.0	5-8	**0.02**
Question 2	8.0	4-8	6.0	2-8	**0.12**
Question 3	6.0	4-8	8.0	6-7.5	**0.24**
Question 4	8.0	6-8.5	7.3	6-10	**0.44**
Question 5	5.5	4-8	7.0	4-9	**0.23**
Question 6	5.0	5-6	5.0	3-8	**0.6**

Questions were scored out of 10. The p value was calculated using the Mann-Whitney test.

Table 4-5 shows the median question 1 score to be significantly higher during the noise exposure than during ambient noise exposure. The higher median scores achieved for question 3 and 5 during noise exposure were not statistically significant and neither were the lower median scores for questions 2 and 4. Median scores for question 6 were the same during both environmental conditions.

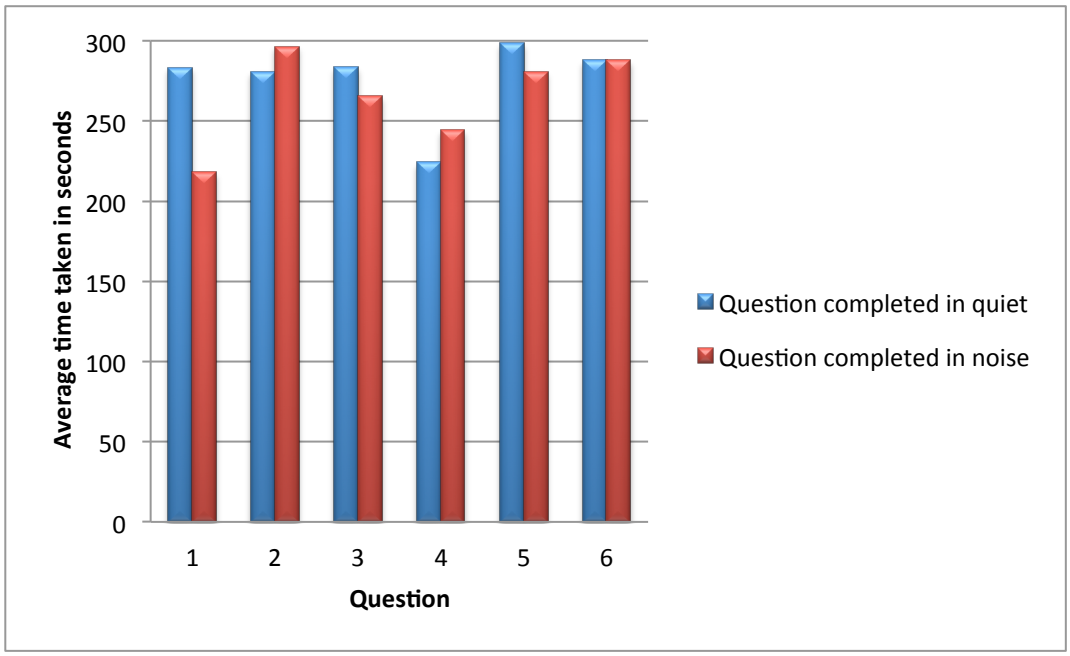

Figure 4- 5 Average time (in seconds) taken by participants completing a particular question in quiet compared to those completing the same question in noise.

Questions 1, 3 and 5 were completed faster during noise exposure. Questions 2, 4 and 6 were completed faster during quiet conditions. The difference between times was 20 seconds or less for stations 2, 3, 5, and 6 with larger differences seen for question 1 (69 seconds) and question 4 (24 seconds).

Table 4- 6 A comparison of question performance: median time for question completion during quiet and noise exposure.

Question	Quiet		Noise		p value
	Median	IQ range	Median	IQ range	
Question 1	300	268-300	201	165-272	**0.01**
Question 2	300	240-300	300	300-300	**0.18**
Question 3	300	273-300	269	237-285	**0.15**
Question 4	220	184-280	244	194-300	**0.03**
Question 5	300	300-300	300	280-300	**0.08**
Question 6	300	265-300	300	276-300	**1.00**

The maximum time possible for each question was five minutes (or 300 seconds as given in the table).

The p value was calculated using the Mann-Whitney test.

Table 4-6 demonstrates that the median time taken to complete question 1 was significantly shorter during higher noise conditions while question 4 took significantly longer to complete during the noise exposure. The difference in median completion time for completion of questions 2, 3, 5 and 6 was not significant.

The proportion of participants who passed or failed each question was assessed with the results given in Table 4-7. The significance of the difference was determined using the Chi-square test.

Table 4- 7 Proportion of participants who passed/failed a particular question in quiet compared to noise.

Question	Quiet				Noise				p value
	Pass ≥6	%	Fail <6	%	Pass ≥6	%	Fail <6	%	
Question 1	8	40%	12	60%	15	71%	6	29%	**0.04**
Question 2	15	71%	6	29%	12	60%	8	40%	**0.44**
Question 3	12	60%	8	40%	17	81%	4	19%	**0.14**
Question 4	17	81%	4	19%	17	85%	3	15%	**0.73**
Question 5	10	50%	10	50%	15	71%	6	29%	**0.16**
Question 6	9	43%	12	57%	9	45%	11	55%	**0.89**

Questions were scored out of 10. A score of ≥6 out of 10 was designated as a pass. The p value was calculated using the Chi-square test.

Table 4-7 demonstrates that a significantly larger number of participants passed question 1 during noise conditions, with more failures seen for that question during ambient "quiet" noise. The difference in the proportions of pass/failures for the other questions in quiet compared to noisy conditions was not significant.

4.3.3 Comparison of task performance in quiet compared to noise

The average score (out of 10) and average time (in seconds, with a maximum possible time of 300 seconds) for each task in each category performed under the quiet and noise conditions were compared by means of the Wilcoxon matched pairs test.

Table 4- 8 Comparison of overall score for three different tasks in quiet and noise.

Task	Quiet		Noise		p value
	Median	IQ range	Median	IQ range	
ECG	6.5	5-8	7.0	6-8	**0.1**
Drug calculation	7.0	4-8	6.0	4-8	**0.21**
Data interpretation	5.0	4-8	6.0	4-8	**0.29**

Questions were scored out of 10. The p value was calculated using the Wilcoxon matched pairs test..

When viewing the different components of the OSCE test there was no significant difference in performance of the three different tasks in quiet compared to noise in terms of median score (see Table 4-8)

Table 4- 9 Comparison of overall time for completion of three different tasks in quiet and noise.

Task	Quiet		Noise		p value
	Median	IQ range	Median	IQ range	
ECG	280	215-300	233	187-279	<0.0001
Drug calculation	300	300-300	300	300-300	0.8
Data interpretation	300	273-300	285	255-300	<0.008

The maximum time possible for each question was 300 seconds (five minutes). The p value was calculated using the Wilcoxon matched pairs test.

Faster completion times (see Table 4-9) were achieved during noise exposure for the ECG interpretation and data interpretation tasks.

Task performance was also analysed by comparing the number of participants that passed/failed each question in order to determine the proportion of poor performers between the two environmental settings.

Table 4- 10 Proportion of pass/fail performances on three different tasks in quiet and noise.

Task	Task performed in quiet				Task performed in noise				p value
	Pass ≥6	%	Fail <6	%	Pass ≥6	%	Fail <6	%	
ECG	25	61%	16	39%	32	78%	9	22%	0.01
Drug calculation	25	61%	16	39%	27	66%	14	34%	0.1
Data interpretation	21	51%	20	49%	26	63%	15	37%	0.4

Questions were scored out of 10. A score of ≥6 out of 10 was designated as a pass. The p value was calculated using the McNemar test.

Table 4-10 demonstrates that a significantly larger proportion of participants achieved a score ≥6 out of 10 for the ECG interpretation under noise conditions with 78% passing the question. While the pass rate for the other two tasks namely, drug calculation and data interpretation, was also slightly higher during noise exposure, the difference was not statistically significant.

4.3.4 Time taken to complete question compared to test score

The total time available for completion of all quiet and noise questions was 900 seconds each. Performance was compared using three different time categories namely 0-800 seconds, 801-859 seconds and 860-900 seconds. Significance was determined using the Chi-square test.

Table 4- 11 Comparison of average test score for participants who completed questions in 0-800 seconds, 801-859 seconds and 860-900 seconds respectively.

Time categories	Quiet questions		Noise questions	
	N	Mean score	N	Mean score
0-800 sec	11	20.6	20	22
801-859 sec	9	21.8	7	20
860-900 sec	21	16.4	14	15
p value	0.017			

Average test score out of 30. The p value was calculated using the Chi-square test.

Table 4-11 demonstrates that there were similar test scores when comparing quiet and noise performance by time categories. Those individuals who took longer to complete the questions also had lower scores in both the quiet and noisy environments. A significantly higher proportion of participants (49%) fell into the faster time category (0-800sec) during the noise conditions compared to the quiet conditions (27%).

4.3.5 Comparison of task score for question performed first compared to second

Due to the fact that the participants were split up between the questions during the testing session, half of the participants completed the first question in each task category first while the others completed the particular question second. The average score (out of 10) for each task category completed first and

second was compared by means of the Wilcoxon matched pairs test in order to assess if there was a learning effect.

Table 4- 12 A comparison of performance of the first and second tasks completed during the OSCE test.

Question	Completed first		Completed second		p value
	Median	IQ range	Median	IQ range	
ECG Q1 & Q4	5.5	4.5-7	7.5	6.5-9	**0.0001**
ECG Q4 & Q1	7.0	6-8.5	7.0	5-8	**0.18**
Drug calculation Q2 & Q5	8.0	2-8	6.0	4-8	**0.89**
Drug calculation Q5 & Q2	6.5	5-9	6.0	4-8	**0.09**
Data interpretation Q3 & Q6	6.0	4-7	5.0	3-6	**0.43**
Data interpretation Q6 & Q3	5.5	5-8	8.0	6-10	**0.03**

Questions were scored out of 10. The p value was calculated using the Wilcoxon matched pairs test.

Table 4-12 demonstrates that there was no significant difference in test score between tasks performed first compared to those performed second for a given task set. The exception to this was the group that completed question 1 first followed by question 4 for the ECG interpretation task and the group that completed question 6 first and question 3 second for the data interpretation task. Question 4 received higher scores when completed second. Question 3 had a higher median score when completed second.

4.3.6 Task performance according to years of experience

Given the fact that there was a range of clinical experience amongst the participants, the average test score (out of 30) and average time for test completion in quiet and noise questions of those participants with less than or equal to six years and those with greater than six years of experience was compared using the Wilcoxon matched pairs test to assess significance. The

performance of those with less than or equal to six years of experience was also compared to those with greater than six years using the Mann-Whitney test.

Table 4- 13 Comparison of overall test score in OSCE test on questions completed in quiet and noise according to years of experience.

		Quiet		Noise		p value 1
Years worked	No. in category	Median	IQ range	Median	IQ range	
≤6	22	17.5	14-21	19.0	14-20	**0.77**
>6	19	21.0	16-23.5	22.3	19-25	**0.059**
	p value 2	0.12		0.02		

Average test score out of 30. The p value 1 was calculated using the Wilcoxon matched pairs test, and p value 2 using the Mann-Whitney test.

Table 4- 14 Comparison of time (in seconds) taken to complete OSCE test questions in quiet and noise according to years of experience.

		Quiet		Noise		p value 1
Years worked	No. in category	Median	IQ range	Median	IQ range	
≤6	22	893	845-900	867	780-879	**0.002**
>6	19	818	741-857	765	718-780	**0.01**
	p value 2	**0.001**		**0.003**		

The maximum time available to complete all of the questions in quiet and noise was 900 seconds respectively. The p value 1 was calculated using the Wilcoxon matched pairs test, and p value 2 using the Mann-Whitney test.

Those participants with greater than six years of clinical experience demonstrated both higher test scores (Table 4.13) as well as faster completion times (Table 4.14) for questions in both quiet and noise conditions when compared to those with less than or equal to six years experience. While thoseparticipants with less than or equal to six years of clinical experience had no difference in test score during quiet and noise exposures, they also

achieved faster competion times during noise exposure. When comparing the group with less than or equal to six years experience to those with more than six years experience, the group with more clinical experience achieved significantly higher scores during noise exposure as well as competing tasks faster than the group with less experience in both ambient noise and noisy conditions.

4.3.7 Task performance of participants with high subjective noise sensitivity

Seventeen of the 41 participants stated that they were “rather” and “very” sensitive to noise, and were thus regarded as having high subjective noise sensitivity. The remaining 24 participants reported low noise sensitivity. The quiet and noise performance of those with high and low subjective noise sensitivity was assessed by comparing overall question score and completion time, with significance determined by the Wilcoxon matched pairs test. The performance of the noise sensitive participants was then compared to the performance of the participants with low subjective noise sensitivity by means of the Mann-Whitney test.

Table 4- 15 Comparison of test score on test questions completed in quiet and noise achieved by participants who demonstrated high subjective noise sensitivity compared to those with low noise sensitivity.

Noise sensitivity		Quiet		Noise		p value 1
	Number	Median	IQ range	Median	IQ range	
High	17	16	13.5-17	19.0	13-22	**0.09**
Low	24	21.5	18-23	20.5	16-25	**0.70**
	p value 2	**0.006**		**0.23**		

Average test score out of 30. The p value 1 was calculated using the Wilcoxon matched pairs test, and p value 2 using the Mann-Whitney test.

Table 4-15 demonstrates participants with high subjective noise had no significant difference in test score during noise exposure. The group that reported low noise sensitivity also achieved similar scores during quiet and noisy conditions. When the performances of the two groups are compared to one another, the only significant finding was that the low noise sensitivity group achieved higher scores than the high noise sensitivity group during quiet conditions.

Table 4- 16 Comparison of time (in seconds) taken to complete test questions in quiet and noise by participants who demonstrated high subjective noise sensitivity compared to those with low noise sensitivity.

Noise sensitivity		Quiet		Noise		p value 1
	Number	Median	IQ range	Median	IQ range	
High	17	898	830-900	840	760-874	0.04
Low	24	843	780-889	778	728-891	0.002
	p value 2	0.06		0.25		

The maximum time available to complete all the questions in quiet and noise was 900 seconds respectively. The p value 1 was calculated using the Wilcoxon matched pairs test, and p value 2 using the Mann-Whitney test.

Both groups completed the stations faster during noise exposure. There was no difference in performance time when comparing the completion time of the low noise sensitivity to the high noise sensitivity group during both quiet and noisy conditions.

4.4 Subjective experience of performance with noise exposure

The post-test questionnaire enquired about symptoms experienced during the testing session. Figure 4-6 shows the number of respondents who experienced the various symptoms enquired about.

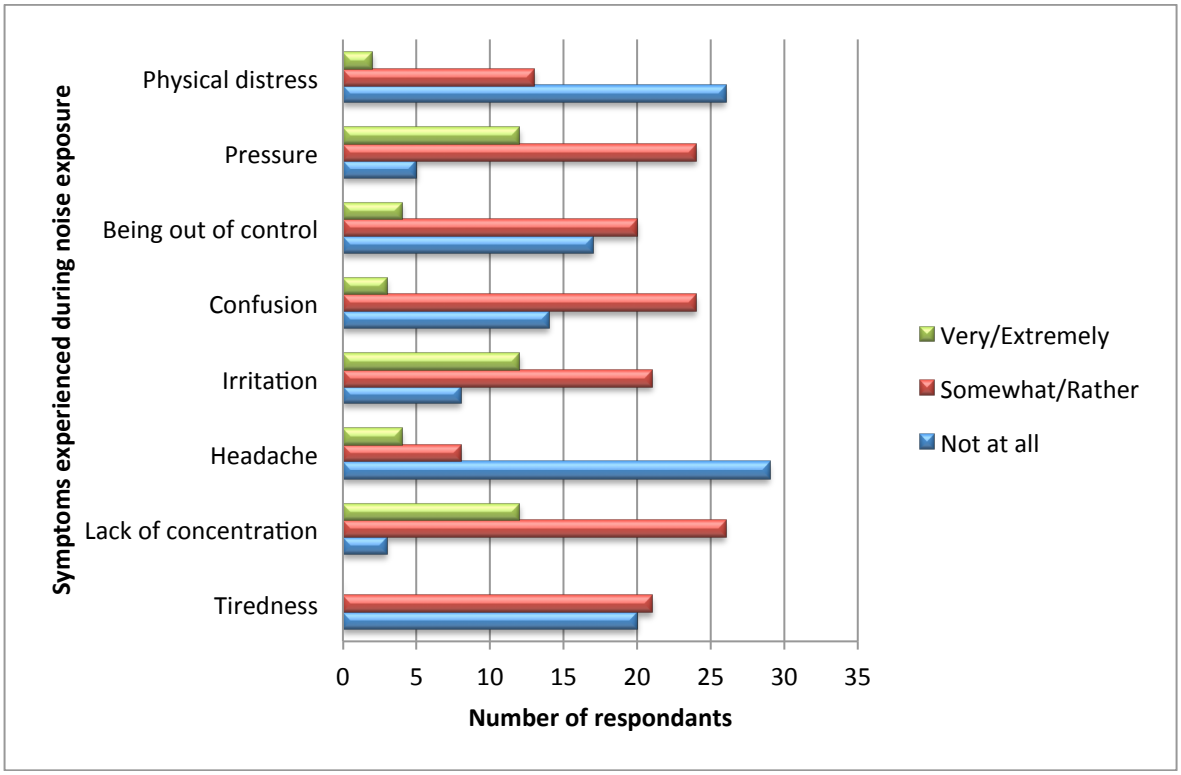

Figure 4- 6 Symptoms reported by participants as a result of the noise exposure during the OSCE test.

The three most common symptoms experienced to varying degrees by the participants included a lack of concentration (93%), pressure (88%) and irritation (81%). Far fewer participants experienced physical symptomatology with less than 50% reporting any degree of physical distress, headache or tiredness.

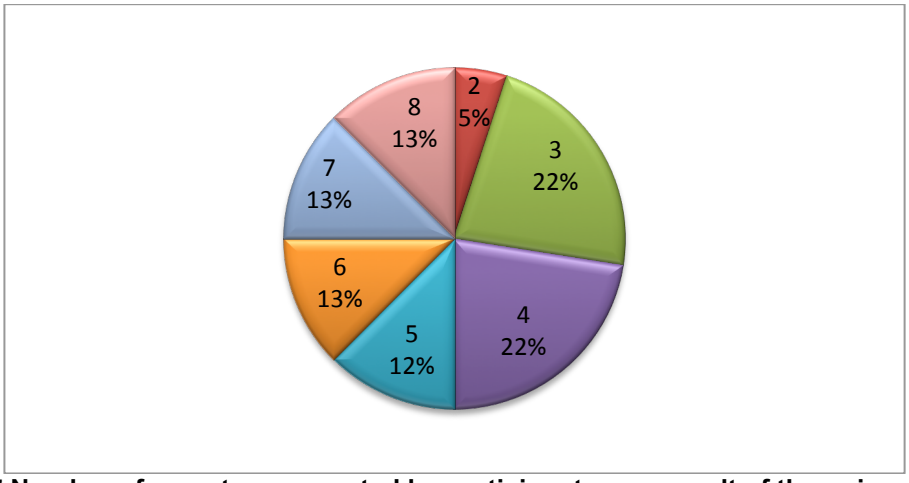

Figure 4- 7 Number of symptoms reported by participants as a result of the noise exposure during the OSCE test.

All of the participants reported at least two symptoms as a result of the noise exposure, with nine individuals reporting three and a further nine reporting four symptoms. Fifty one percent of the participants reported five or more symptoms (see Figure 4-7).

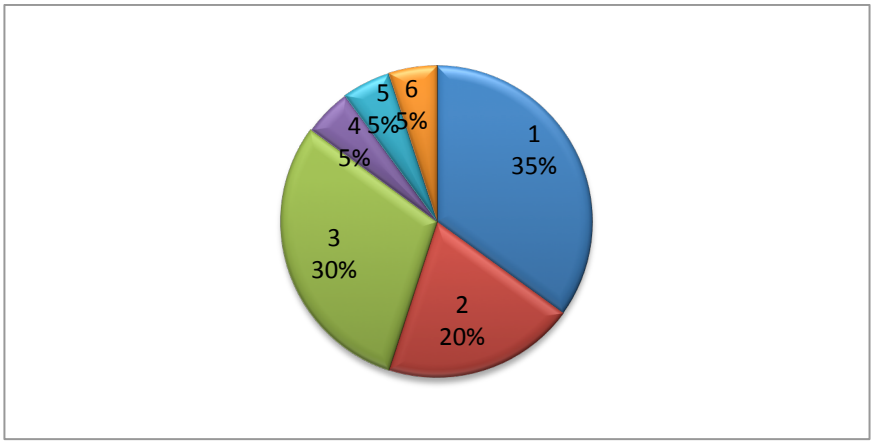

Figure 4- 8 Number of severe symptoms (i.e. rated as "very/extremely" on a five-point rating scale) reported by the group reporting severe symptoms as a result of the noise exposure during the OSCE test.

Of the 41 participants, 20 reported at least one severe symptom and of the group reporting a severe symptom, 45% reported three or more severe symptoms (see Figure 4-8).

Displayed in Figure 4-9 are the results of the participants' perceived impact of the noise on their performance of the different tasks during the OSCE test.

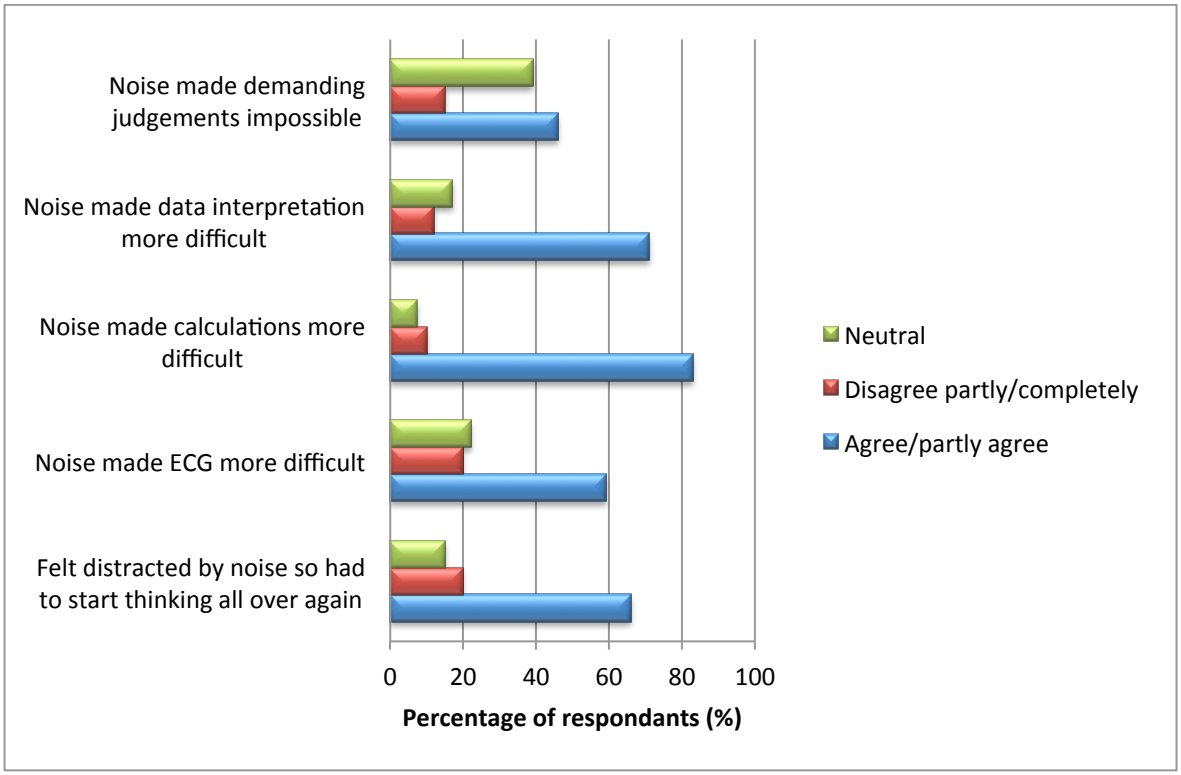

Figure 4- 9 Results from the questionnaire regarding perceived impact of noise on task performance.

As displayed in Figure 4-9, the majority of participants felt that the noise made all aspects of the OSCE test more difficult, with 66% reporting that they were so distracted by the noise that they had to start thinking all over again. Forty six percent of the participants felt that noise would make demanding judgements impossible. The task that was felt to be made most difficult by the noise exposure was the drug calculation task, with 80% of participants reporting difficulty with this aspect of the test during noise conditions. Seventy percent of participants felt that noise made the data interpretation more difficult, while only half felt that the ECG interpretation was more difficult during noise exposure.

Participants were also given an open-ended question which asked for additional comments on their experience during the OSCE testing session. Some of the answers given by the participants are presented in Table 4-17.

Table 4- 17 Additional comments made by participants to an open-ended question enquiring about their experience of the sound environment during OSCE testing.

Additional comments on impact of noise
Felt a lack of concentration when quiet
Noise disturbed my thinking, was distracting, had to keep double checking everything
Could not think well in noise
Noise conditions were distracting
Noise created panic which resulted in rushing through questions
Poor concentration due to noise
The noise was disrupting
Had to start over with calculations as lost concentration in noise
Clinical information was difficult
Noise was tiring and disturbing leading to difficulty concentrating and headache
I preferred the noise, it woke me up and got the adrenaline going
Much easier when quiet
Increased ability to think rationally in quiet environment
Contrast between quiet and noise was too great
Noise distracted me. I found myself more relaxed when it was quiet
Noise made concentration difficult but I think my performance was equal in noise and quiet
I deliberately concentrated more in the noise
Could think clearer in quiet
Medical noises weren't distracting but loud talking/drilling/sirens were
Calculations were harder in noise than the data analysis in noise
Noise made me nervous and lead to calculation errors
I felt that I could not concentrate and do the calculations in the noise

The majority of the comments made by the participants stated that they had difficulty concentrating and that the noise was distracting. Others described a sense of pressure created by the noise with a disruption of thinking.

Chapter 5 **DISCUSSION**

This study rendered some interesting results demonstrating a range of noise effects from none at all, to improvements in performance particularly with regards to speed of task performance. In addition to this, one of the most significant findings was the additional strain and pressure experienced by participants as a result of noise exposure suggesting that noise needs to be considered as an occupational hazard and stressor which therefore needs to be addressed.

5.1 OSCE test performance

5.1.1 Comparison of overall performance in quiet compared to noise

This study demonstrated no significant difference in the overall average test score between quiet and noise exposures (Table 4-4). Studies on the effects of noise on performance have rendered variable results (8). While some found effects on vigilance performance to be equivocal, others have shown a degradation in the quality of sustained attention, when performing tasks that placed high information-processing demands on the participant, in noise levels at or above 90dB, with noise effects reliably observed after exposures between 90 and 100dB (37, 41). This may explain why no statistically significant difference was seen in the overall test score i.e. that the noise levels used were potentially not high enough. As noted by Hockey (41), noise exposure has both positive and negative effects on performance. Negative effects are less likely to be seen early on in performance. The noise exposure may therefore not have been long enough resulting in performance being unaffected. Another explanation for the lack of difference in overall test score may be the fact that participants were given alternating quiet and noise

exposures, thereby providing some relief from the noise. Stave (31), when studying long-term pilot performance, found that vigilance performance was effectively maintained if participants were given short rest pauses. Participants were however unable to maintain performance if required to work continuously without rest. The alternating quiet questions provided relief from the noise stressor allowing participants “recovery time”, and could explain why they were able to maintain performance. In a busy ED, there is generally no relief from the noisy environment. Without “recovery” periods, there may be degradation in performance. The study also created a set time for exposure to noise, which does not exist in clinical practice. Therefore, performance may still be adversely affected in these settings.

While a difference in overall test score was not seen, there was a significant difference in the time taken to complete the tasks between the two exposures. Overall time taken to complete all tasks during noise exposure was faster than that during quiet (Table 4-4). The increased speed of performance during noise exposure may point to the arousal effect of noise. The arousal effect of noise as well as the increased pressure exerted by the noise, created a sense of urgency and the need to work faster. This conclusion was reinforced by the following comments from participants:

- “The noise created panic which resulted in rushing through the questions.”
- “I preferred the noise, it woke me up and got the adrenaline going.”
- “The noise made me nervous.”

Other participants commented that the quiet environment was too quiet and felt distracted by it. These comments highlight the arousal effects of noise. Becker *et al*. (37) found that if sound levels were high enough to have a masking effect on acoustic feedback or inner speech, it resulted in immediately observed performance decrements. In addition to this it was found that lower levels of noise produced arousal which initially improved performance. This arousal is related to the effect of mild noise stress on the reticular activating system, hippocampus and amygdala. Effects on these areas result in improved memory functions (35). Therefore, the noise during the OSCE test seems to have had an arousing effect on the participants. Since the levels used were not excessive, the noise created a positive stimulus which enabled participants to complete the tasks during the noise exposure at a faster rate.

5.1.2 Comparison of question performance in quiet compared to noise

When comparing the individual question performance, in general, there was no significant difference in performance on the same question when completed in quiet compared to noise (Table 4-5). The two exceptions to this were:

- Question 1, for which participants scored better during noise exposure (7/10) compared to in the quiet ambient environment (5.2/10, p value= 0.007).
- Question 2 for which participants scored better (6.8/10) in the quiet compared to the noise (5.3/10, p=0.02).

Question 1 required recognition of an ECG demonstrating atrial fibrillation. Atrial fibrillation has a very characteristic pattern which may have been easy to identify, therefore rendering the task fairly simple. Hockey (41) described that when noise resulted in improved performance as seen here, it was likely to occur with simple tasks. Question 2 required the calculation of drug dosages, which is a more complex task. While the lower scores for question 2 during noise exposure were not statistically significant, the range of scores were lowest for this question. Staal (8) noted that the negative effects of noise were more likely to be seen with more complex tasks, which could explain the poorer performance on the second question with noise exposure.

A comparison of time taken to complete each question performed in quiet compared to noise (Figure 4-5) revealed faster performance on three of the six questions with noise exposure. The faster performance was however only significant for question 1. This faster performance, along with the fact that a larger proportion of the participants performed faster in the noise (48% compared 27%) (Table 4-11), may once again point to the activation effect of noise. Interestingly, completion of question 4 (ECG) was significantly slower during noise exposure. Participants may have found this question more complex and challenging, thereby, demonstrating degradation in performance with noise exposure due to increased time for completion required to achieve similar scores (Table 4-5).

When comparing the proportion of participants who passed and failed each question, (Table 4-7) there was no significant difference in the pass rate

between quiet and noise with the exception of question 1. Question 1 had a significantly higher pass rate during noise exposure. Given the fact that only one of the six questions showed a difference, caution should be exercised when attributing noise as the cause of the difference. Fewer participants commented that the ECG interpretation was made more difficult by noise. It is possible that the task of ECG interpretation is more “routine” and was therefore perceived as being easier by the participants. As a result, the activating effects of noise demonstrated improvements in the performance of this task.

5.1.3 Comparison of task performance in quiet compared to noise

When comparing task performance it was found that while there was no significant difference in test scores for the three different tasks (Table 4-8), participants achieved faster completion times for the ECG and data interpretation tasks during noise exposure (Table 4-9). This difference can be explained by the fact that the ECG and data interpretation tasks were perceived as being “easier” therefore benefiting from the activation effect of noise. The drug calculation task was more complex and was experienced as more difficult by participants, therefore negating the activation effect of noise. This conclusion is reinforced by the fact that participants demonstrated a higher pass rate on the ECG task during noise exposure (Table 4-10) along with comments from participants that the calculations were harder than the data analysis during noise (Table 4-17).

5.1.4 Time taken to complete question compared to test score

There was very little difference in the test score of participants completing the questions in the different time categories. Those participants who look longer to complete the questions also achieved lower scores in both the quiet and noise environments (Table 4-11). Based on this finding, it can be suggested that the poorer performance may have been related to difficulty in thinking through and processing the information as opposed to environmental influences. Conversely, there were also a higher proportion of the participants that performed the tasks faster during the noise exposure, due to the fact that the noise may have had an activating effect on participants, enhancing arousal and thereby enhancing task performance.

5.1.5 Comparison of task score for question performed first compared to second

In order to exclude a learning effect, performances of the first and second tasks for each task were compared (Table 4-12). For the majority of the questions there was no significant difference in test score between the first task performed in the paired questions compared to that of the second. The exceptions to this were the two of the question sets for:

- The group that completed ECG question 1 first followed by question 4
- The group that completed the data interpretation question 6 followed by question 3.

While the second ECG question demonstrated higher scores, subgroup analysis revealed that the difference was due to the fact that those questions completed during noise exposure received higher scores (5.5/10 in quiet and

7.3/10 in noise) and therefore may signify a noise effect as opposed to a learning effect. The group that completed the data interpretation question 6 first followed by question 3 achieved higher median scores for the question completed second. Subgroup analysis of this group failed to demonstrate a noise effect. Given the fact that this was the only task set that had an unexplained improvement in score when completed second, caution should be exercised in attributing the difference to a learning effect. It can therefore be concluded that the results were not likely to have been affected by a learning effect.

5.1.6 Task performance according to years of experience

The comparison of participants with “less than or equal to six years experience” and those with “greater than six years experience” (Table 4-13, 4-14) demonstrated that participants with greater than six years experience were faster in the noise compared to those with less experience, and had significantly higher scores during noise exposure. This finding may be accounted for by the fact that these individuals may have undergone greater adaptation to noisy environments due to longer exposure and are therefore able to cope better and are therefore activated more by the noise. This finding is supported by results from the study by Topf (63) who found that nurses with more years of clinical experience had less heart rate elevations as a result of noise exposure as well as lower annoyance ratings. The faster times and higher scores demonstrated in both quiet and noise by the “greater than six years experience” category, when compared to those with less experience, can be explained by the fact that those with longer experience have become

more proficient with the processing and manipulation of clinical data and well as greater adaptation to noise as a stressor resulting in better coping. It may be that the given tasks become more routine with greater experience similar to the automatism associated with driving a car for someone with ten years driving experience compared to a learner driver. It also needs to be considered that those participants who were older did not experience the noise at as high a level as their younger counterparts due to potential age-related deterioration in hearing (presbyacusis).

5.2 Work sound environment of participants

A large proportion of the participants enrolled in the study felt that their work environment was noisy (Figure 4-2) with 58.5% reporting moderate to severe degrees of disturbance by the noise (Figure 4-3). This finding highlights the fact that local hospital work environments are likely to be just as noisy as those described in other countries (2,5-7,9). This supports the need for investigating and addressing the effects of hospital noise on staff and patients. Bayo *et al*. (60) reported similar levels of staff annoyance by hospital noise, with 61% of interviewees reporting being “very annoyed” by noise levels.

Noise has been identified as a significant stressor (40). The fact that 95% of participants reported some level of disturbance by their workplace noise suggests that it is likely that workplace noise is contributing to stress levels of healthcare professionals within the South African setting. If work conditions were ideal, isolated noise stress may be manageable, but this unfortunately is not the case. The South African healthcare setting is marred by many challenges related to

limited resources e.g. high patient volumes and insufficient staffing. It is on this background within the South African setting, that the issue of noise as a stressor needs to be understood. This additional stressor may just be the "final straw to break the camel's back" resulting in employee illness and injury described by Morrison *et al. (*58). This finding once again highlights the importance of workplace noise, making it a priority that should be addressed if employee wellbeing is to be a priority for hospital administration.

Some practical suggestions for noise reduction in the ED include:

- Educating staff members about the hazard of noise for both patients and healthcare professionals and thereby encouraging them to speak softly (59).
- Relocating the nurses' station and patient waiting areas so that it is away for the examination cubicles and resuscitation area (48).
- Reducing unnecessary human traffic through the ED.
- Reducing the volumes of monitoring equipment in the resuscitation area (48).
- Using sound absorbent material for cubicle dividers (45).
- Creating separate areas for disruptive patients (e.g. psychotic patients).

5.3 Subjective noise sensitivity

There was no difference in test performance with noise exposure, when comparing test scores, between those participants who stated that they had high subjective noise sensitivity and those with a low sensitivity. Both groups were faster during noise exposure but the difference was only significant for the low noise sensitivity

group. This could mean that the activation effect of noise was less in the noise sensitive group with the noise creating more anxiety than activation, and thus placing strain on coping abilities, due to an increased sensitivity. This suggestion is supported by the fact that the participants with high subjective noise sensitivity reported more symptoms during the noise exposure than those with low sensitivity. Of the 21 participants that reported five or more symptoms, 14 (66%) were in the high sensitivity category. Twelve (70%) of the 17 noise sensitive participants reported experiencing six or more symptoms during the noise exposure. This finding is in keeping with other studies that have found a range of effects of noise on the performance of noise sensitive participants from none to moderate, but significant increases in levels of annoyance (30, 34, 38) . Belojevic *et al*. (30) had similar findings and described how annoyance created by noise was lowest in noise tolerant participants. Topf (19) described the same trend of annoyance being demonstrated in noise sensitive individuals at several levels of measured noise, whereas those with lower noise sensitivity only expressing annoyance at high levels. Therefore, if sound levels had been higher during the OSCE testing, participants who are more noise tolerant may have reported a greater number of severe symptoms. In the hospital environment, where the sound levels often exceed those achieved during the OSCE test, annoyance and the resultant fatigue, irritation and physical symptoms are likely to be seen in all individuals irrespective of noise sensitivity (1,2,5-7,9,61).

5.4 Subjective experience of performance during noise exposure

While there was no degradation in overall performance, the results of the post-test questionnaire demonstrate that participants experienced a significantly higher

workload during the test as a result of the noise exposure. This finding is supported by Becker's (37) observations that while noise effects were not demonstrated in performance degradation, there were significant workload elevations which could lead to other negative consequences namely: fatigue, mood changes and absenteeism. The elevated workload and environmental stressor of the noise resulted in participants reporting a variety of symptoms. Forty eight percent of participants classified at least one of the reported symptoms as severe. Staal (8) reported similar trends after observing that noise exposure led to greater self-reported distress as the noise decibels increased. These subjective reactions may influence long-term performance, and when exposure is prolonged, may affect overall health and well-being.

The most common symptoms reported by participants were a lack of concentration, feelings of pressure, irritation and confusion. Fifty one percent of participants reported five or more symptoms and 20 reported at least one severe symptom. This is significant since it highlights the ability of noise to elicit stress responses as described by Persson Wayne *et al*. (25). It is also in keeping with findings by Topf and Dillon (63) who found that noise exposure resulted in significant workplace stress. This resulted in an increased frequency of headaches and burnout symptoms. The experience of this high rate of negative noise-induced stress symptomatology following such a short exposure raises concern of the cumulative effect of workplace noise over an eight hour or longer work shift period. Cumulative noise-stress following this prolonged period of exposure is likely to be even more significant, therefore placing healthcare professionals at a significant

risk of burnout, especially when combined with other stressors that are so typical of the South African work environment.

The fact that 76% of participants found at least two of the three tasks more difficult during noise exposure is in keeping with Hockey's (41) finding that noise stress causes a reduction in the individual's confidence in his/her ability to perform the task at hand. More participants felt that the drug calculations (83%) were more difficult with noise exposure when compared to the ECG interpretation (59%) and data interpretation (71%). In addition to this, many of the comments made by participants to the open-ended question on the noise exposure pertained to the fact that the calculations were more difficult due to a difficulty in concentrating as a result of the noise exposure. An explanation for this may be that the calculating task placed more strain on mental capacity thereby leaving very little spare capacity for the participants to cope with the noise, which has been demonstrated by other studies (30). As individuals are placed under strain, they exert greater effort to deal with the stress, which was demonstrated in this study by a comment from one of the participants who stated, "I deliberately concentrated more in the noise." This increased effort is one of the factors that, with prolonged noise exposure, results in increased work stress, fatigue and burnout risk, as has been described (25, 63). The increased effort put forth by individuals results in significantly elevated workload which in and of itself leads to fatigue (76). Ramsay (76) noted that the onset of fatigue as a result of noise exposure results in errors. Initially the errors are minor, which may have been the case in the OSCE test, where minor errors may have been made but were picked up and corrected, therefore resulting in little difference in test score. This idea is supported by the

fact that some participants commented that they “had to start over again with calculations” and “had to keep double checking everything.” The expected degradation in performance that did not occur should not be reassuring as the noise exposure was short. Prolonged exposure may result in fatigue which is likely to have a greater impact on performance and has the potential of leading to mistakes which may have disastrous consequences for patients (76).

Fatigue is a common complaint among healthcare professionals with potentially serious consequences (81). It has been found that many USA residents have stated that they have made errors as a result of fatigue (81). On the 14th of December 2011 the Joint Commission on Accreditation of Health Care Organisations (JCAHO) released a Sentinel Event Alert pertaining to the risks of fatigue and patient safety (82). In this report, great concern was raised regarding the documented link between healthcare worker fatigue and adverse patient events (81). In 1999, the Institute of Medicine reported that medical errors contributed to up to 98000 deaths and an excess of one million injuries in the USA each year. These figures were alarming and led to a great focus on interventions to improve patient safety (83). Ten years later, Landrigan *et al*. (83) conducted a study in order to assess whether there was any improvement in patient safety since the implementation of safety interventions. A review of ten North Carolina hospitals revealed that patient harm remained a common problem with a 25.1 per 100 admissions harm rate, and thereby concluded that patient safety efforts need to continue, if not be heightened, in order to achieve transformation with regards to patient safety (83). While most studies have focused on sleep deprivation as the cause of fatigue, West *et al*. (84) demonstrated that it was not only sleep

deprivation but also resident distress that was a contributing factor in self-reported medical errors. In addition to resident distress, additional factors such as noise and pressure contribute to fatigue (85). As demonstrated in this and other studies (8,10,17), noise exposure places significant additional stress on individuals. In the individual who is fatigued and sleep-deprived, function is at the upper limit of their coping ability. The additional stressor of noise exposure may be the factor to "push" such an individual "over the edge". This may result in potentially fatal medical errors. It is on this background that the JCAHO alert relating to the effects of fatigue on medical error rate needs to be taken seriously and that the sources of fatigue be addressed. This includes environmental factors such as noise. This will potentially decrease the number of medical errors thereby ensuring a greater quality of patient care.

Participants stated that they were able to cope better with "medical noises" but found other noises more disturbing. This finding may be explained by the fact that different noise characteristics result in different levels of annoyance (23). It also demonstrates that individuals participating in this study may have adapted to workplace noise. Meis (15) explained that individuals regularly exposed to noise adapt and conversely may perform sub-optimally in quiet environments. This was also demonstrated by those participants with greater than six years of experience who had significantly lower scores in the quiet and also took longer to complete questions in the quiet environment. All of the individuals that participated in the study work in busy academic hospitals. Sixty three percent stated that they were exposed to high noise levels on a daily basis. This means that they may have

already adapted to the noise, therefore allowing adequate functioning during noise exposure.

Participants commented that the drilling noises and sirens were particularly disturbing. This may be related to the fact that the sounds of drilling, banging and sirens were interspersed randomly amongst the other sounds and were thus unpredictable. Other studies have demonstrated that uncontrollable and unpredictable noise is more disturbing than predictable noise and causes the most significant impact on performance (14, 44).

5.5 Recommendations

Noise is a well-recognised problem within all areas of the hospital environment (45). Noise has numerous adverse effects on both staff and patients, but despite this, very little is done to reduce noise levels (49). This study has highlighted some of the negative effects of noise exposure on healthcare professionals and reinforces the call to focus on noise reduction in the hospital environment. Addressing the problem of hospital noise requires (8):

1. Awareness of the problem
2. Addressing the acoustical design of hospitals
3. Allocating “quiet” areas in hospitals
4. Modulating alarm systems and equipment
5. Use of noise cancellation technology and “beneficial noise”
6. Staff education

Hospital noise is everyone’s problem and everyone should make an effort to reduce noise levels.

5.6 Limitations of this study

In Ljungberg's (26) work, no difference was found in performance between different environmental noise exposures. It was thought that the environmental stimulus was not provocative enough. In order to generate additional pressure of participants, and therefore a higher workload, a time limit was imposed on the participants. The isolation of these two stressors (time limit and noise) in this study may not have placed a high enough demand on participants. In reality, healthcare professionals are exposed to many stressors at once, e.g. visual distractions, chaotic environments, urgency pressures etc., which are all cumulative. This may push the individual beyond their ability to cope, and in so doing, larger effects secondary to noise are more likely to be demonstrated. Therefore the isolation of noise alone as a stressor may be a limitation in this study when looking at performance degradation, and testing of participants with exposure to a combination of stressors may be necessary. In addition to this, the fact that fatigued (i.e. post call) doctors were excluded may have served as a confounder. These individuals were excluded since the small sample size would have made multivarient analysis difficult thereby making it impossible to separate out noise effects from possible fatigue effects.

Another limitation of this study is the fact that the participants knew that they were being tested. Stave (31) demonstrated that performance is dependent on motivation, and that despite exposure to stressors, participants are able to maintain performance if motivated to do so. Given the general competitive and achieving nature of individuals who enter the field of medicine, the participants in this study were challenged by the test and therefore had high levels of motivation,

which may have compensated for the negative effects of the noise. This suggestion was reinforced by the fact that many of the participants were very concerned with the answers to the questions after the testing session and even wanted to know their test results.

The lack of blinding during the study may also have been a limiting factor. The marker of the tests was not blinded to the fact that the question was performed in quiet or noise. The marker may therefore have subconsciously favoured poorer performance during noise exposure and therefore been stricter on scoring those questions. This possibility was offset by the fact that a marking memorandum was used in order to obtain standardisation with mark allocation.

A further limitation of this study is in its translation to reality. When healthcare professionals are required to perform in an emergency environment the stakes are often life and death thereby placing huge demand on them. This will result in heightened arousal and may allow the healthcare worker to block out distracting noise in order to focus on the task at hand. In the OSCE scenarios there was no real pressure apart from the imposed time constraint – which the participant may or may not have taken seriously. A patient's life was not at risk during the OSCE scenario. Participants also had a specified, limited time for noise exposure, with relief after each noise question, allowing a period of "rest" from the noise. This rest may have provided enough recovery time so that the negative effects of noise with prolonged exposure were not seen.

This study only tested cognitive tasks. In actual emergency environments, individuals are required to perform both cognitive and physical tasks. Further testing incorporating both cognitive and psychomotor tasks may render different results.

The fact that noise exposure was limited to 85dB, to avoid any potential risk from noise-induced hearing loss, exposed participants to lower levels of noise than they would routinely be exposed to in a hospital environment. Therefore this lower sound level was likely not to have been provocative enough to fully appreciate the impact of hospital noise levels on performance. It is therefore likely, that if higher sound levels were used, a greater degradation may have been seen in performance during noise exposure. In addition to this, pre-existing presbyacusis may have resulted in lower perceived sound levels in older participants.

Additional multivariant analysis may have been desired but was not possible as the sample generated was done so for the purpose of comparing quiet performance to noise performance. Therefore, further multivariant analysis would have rendered samples in each category too small for comparison. In addition, while no difference was seen in overall performance, it must be noted that the study design was not powered for non-paired analysis. Non-paired analysis was however carried out in order to assess if there was a difference. Therefore, if a greater sample size was used, greater differences may have been seen.

Since the noise exposure was not long enough and the levels not high enough it may affect the translation of the study results into reality. While these limitations

are acknowledged; the study still rendered useful results – particularly those pertaining to the stress effects of noise on individuals.

5.7 Strengths of this study

Participants in this study had a range of clinical experience therefore giving adequate representation of doctors and demonstrating that adequate performance on the test used was not dependant on clinical experience and knowledge, but rather mental processing.

This study used actual pre-recorded emergency department noise therefore creating a “real sound” environment as opposed to simply playing haphazard sounds.

The tasks using in the study were actual tasks that healthcare professionals are required to perform during everyday duties, therefore having greater relevance for testing clinical processes as opposed to using a testing tool that is not related to clinical medicine (e.g. psychometric tests used in other studies).

Chapter 6 **CONCLUSIONS**

The hospital environments in which the doctors who participated in this study work are likely to be just as noisy as those reported in other studies and act as a significant stressor for many of these healthcare professionals therefore highlighting the need to address noise management within South African Hospitals.

This study showed no difference in cognitive performance in a quiet compared to a noisy environment when comparing overall test scores. Participants, however, performed most tasks faster during noise exposure, most likely due to the pressure and arousal effect of the noise. Deterioration in functionality might be seen with higher levels of noise and/or longer exposure.

Improved performance during noise exposure was demonstrated on simple tasks with some degradation in performance seen on more complex tasks that involved drug calculations suggesting that noise is more likely to have a detrimental effect on the performance of complex tasks.

Based on the data from this study it can be suggested that participants with longer clinical experience may have undergone adaptation to workplace noise and are therefore able to function better in a noisy environment as well as being more proficient at manipulating clinical data when compared to their junior counterparts.

Participants with high subjective noise sensitivity are likely to experience greater annoyance and symptomatology as a result of noise exposure than those with low noise sensitivity while still being able to perform at adequate levels.

Despite the lack of performance degradation, 65% of participants found the noise to be distracting with 88% of participants reporting significant degrees of distress. With prolonged exposure, this may contribute to fatigue, stress and eventual burnout, especially when combined with other job-related stressors typical of an Emergency Department environment.

Future research assessing the effect of combined stressors on healthcare professionals' cognitive functioning will be useful to assess the cumulative effect of these stressors on performance. Additional studies assessing the effects of prolonged noise exposure and higher noise levels on performance are also needed.

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APPENDIX 1 Human Research Ethics Committee clearance

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M110564

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/39 Dr Lindy-Lee Fleischer

CLEARANCE CERTIFICATE	M110564
PROJECT	Does Loud Noise Affect the Clinical Decision Making Processes of Healthcare Professionals in Simulated Emergency Setting?
INVESTIGATORS	Dr Lindy-Lee Fleischer .
DEPARTMENT	Department of Emergency Medicine
DATE CONSIDERED	27/05/2011
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 27/05/2011 CHAIRPERSON .....
(Professor PE Cleaton-Jones)

*"Guidelines for written 'informed consent' attached where applicable.
cc Supervisor : Dr Lara Goldstein

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and ONE COPY returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. I agree to a completion of a yearly progress report.
PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.

APPENDIX 2 OSCE test used during study

Question 1:

Mrs A. is a 64 year old female who presents to the Emergency Department (ED) complaining of chest pain and shortness of breath. She was busy washing the dishes when she suddenly became dizzy and needed to sit down. Her vital signs are as follows:

- BP= 100/40mmHg
- RR= 14bpm
- HGT = 4,7 mmol/l
- Oxygen saturation= 92% on Room Air.

Look at the ECG provided and answer the questions. (An ECG of atrial fibrillation was provided. Participants were asked to comment on rate, rhythm, QRS axis, P wave, ST segment, T wave and provide a diagnosis.)

Question 2

Mr M is a 50 year old male who fell asleep before blowing out the candle in his shack. The candle fell over and his shack caught alight. He presents to the ED with deep partial thickness burns to his entire anterior abdomen (9%) and chest wall (9%) as well as circumferential burns to both his arms (each arm = 9%).

1. Calculate the total resuscitation fluid requirement for Mr M according to the Parkland formula (4ml/kg/BSA burnt) if he weighs 80 kg.

2. Calculate the flow rate per hour for the fluid administration for the first 8 hours and next 16 hours, if half the total resuscitation fluids must be given in the first 8 hours and the remaining half in the next 16 hours.

3. Mr M is complaining of severe pain for which you want to administer a morphine infusion. The morphine solution available is 50mg in 1000ml. You want to give the patient and infusion of 1mg/hr. What infusion rate will you set in ml/hour?

One week later Mr M is not doing well. His wounds are weeping and offensive. His vital signs are as follows:

- BP= 80/60mmHg
- HR= 140bpm
- Temperature= $39^{O}C$
- RR= 20bpm
- Oxygen Saturation= 95% on Room Air.

4. Sepsis causes Mr M's blood glucose to drop to 2,5mmol/l. You ask the nursing sister to administer 50ml of 50% dextrose IV as a bolus. How many grams of glucose is in the 50ml ampoule?

Question 3

You are on duty in small regional hospital ED out in a rural area. There is a bus accident 4 km away from the hospital on a mountain pass. There are 60 injured passengers. You are called to go assist in triaging the patient's based on the revised trauma score.

The Revised Trauma Score includes the following:

Glasgow Coma Scale (GCS)	Systolic Blood Pressure (SBP)	Respiratory Rate (RR)	Coded Value
13-15	>89	10-29	**4**
9-12	76-89	>29	**3**
6-8	50-75	6-9	**2**
4-5	1-49	1-5	**1**
3	0	0	**0**

When using the score in triage, patients with the score of 12 = Delayed, 11 = Urgent, 10-3 = Immediate and <3 = Morgue.

Calculate the trauma score for the following patients and provide a triage priority for each:

1. A 73 year old female is shouting loudly that her leg is very painful. She is breathing at a normal rate. She has a large bruise over her left shin.

2. A 15 year old girl who moans and flexes her arms when pinched but does not open her eyes. Her blood pressure is 100/60mmHg, heart rate is 120bpm and respiratory rate is 18.

3. A 40 year old male is lying motionless and is unresponsive to pain. He has a blood pressure of 70 systolic, a heart rate of 48bpm and a respiratory rate of 5. He has multiple facial and chest wall injuries.

4. A 29 year old male opens his eyes only when spoken to but appears confused and pulls away when you touch his right leg. His heart rate is 115bpm, blood pressure is 90/68mmHg and is breathing at a rate of 16bpm. His right thigh is swollen and appears deformed, with shortening of the right leg.

5. A 16 year old boy only responds by groaning when you move his obviously fractured left leg, lying motionless with eyes closed. His blood pressure is 60mmHg by palpation, heart rate is 120 bpm and respiratory rate is 20 bpm.

Question 4

Mr E is a 48 year old male who presents to the EDcomplaining of severe heartburn. He has been drinking antacids for his heartburn but today he is not experiencing any relief. He is a diabetic and hypertensive with a 20 pack/year smoking history.

- BP= 90/65mmHg
- RR= 16bpm
- HGT = 9,0 mmol/l
- Oxygen saturation= 95% on non-rebreather mask O_2
- Temperature= 36^oC

His ECG is done on arrival. Look at the ECG and provide notes on his initial ECG. (An ECG of a STEMI was provided. Participants were asked to comment on rate, rhythm, QRS axis, P wave, ST segment, T wave and provide a diagnosis.)

Question 5

Master S is a 7 year old male who presents to the ED on a friday afternoon following involvement in a motor vehicle accident. He has sustained head injuries and a large laceration to the anterior right thigh. He is fully resuscitated according to ATLS principles. He is haemodynamically stable with no active

bleeding from the leg wound. The CT scan of his brain reveals no abnormalities, but he begins to have continuous seizures unresponsive to benzodiazepines. You decide to administer a loading dose of phenytoin.

1. If the patient weighs 20kg, calculate the loading dose of phenytoin (20mg/kg).

2. You have a 120mg/5ml ampoule of phenytoin and 200ml of normal saline. Calculate how much (ml) of the phenytoin you would add to the 200ml of saline if you want to administer the entire 200ml normal saline.

3. What would the flow rate (ml/hr) be if you want to administer the phenytoin over 30 minutes?

You want to suture his leg wound using local anaesthetic but are concerned about toxic doses since the wound is so large.

4. If you only have a 2% lignocaine solution in the unit, calculate how many ml of this solution can be used on him before the maximum dosage is exceeded. (maximum dose of lignocaine without adrenaline = 3mg/kg).

A few days later Master S is doing very well in the high care unit. He still has some pain and you opt to administer oral analgesia.

5. Your drug of choice is paracetamol. The dose is 10mg/kg 6hrly. If the syrup contains 120mg in 5ml calculate how many ml you would administer.

Question 6

The Emergency Department you are working has introduced a new triage system that utilises the South African Triage score. You have been allocated to assist the nursing staff in becoming familiar with the scoring system and spend the day in the triage area. Using the triage card provided allocate a triage score to the five patients below and state what colour of priority they are given.

1. Mrs A is a 70 year old female who walks in complaining of chest pain for the past 2 days. The pain is right sided and is worsening in severity. She describes the pain as being "pressing in nature". She has a history of hypertension and is overweight. Her vital signs are as follows: BP=149/95mmHg, HR=88bpm, RR=14bpm, HGT=4,6mmol/l, Temp=36°C.

2. Mr B is a 45 year old male who is brought in by his family members in a wheelchair. He is too weak to stand following an episode of diarrhoea that has lasted for 1 week. He looks wasted, is wearing a nappy and is unable to answer questions appropriately. His vital signs are as follows: BP=89/60mmHg, HR=140bpm, RR=20bpm, HGT= 2,3mmol/l, Temp=35°C.

3. Miss C is a 16 year old female who is brought in on a stretcher by the paramedics. She has been assaulted by her boyfriend with a blunt object. She has multiple stab wounds to the trunk. She responds when spoken to by opening her eyes. Her vital signs are as follows: BP=100/60mmHg, HR=120 bpm, RR=24 bpm, HGT=5,0mmol/l, Temp=36°C.

4. Mr D is an 89 year old male who is brought in by his son. He walks in leaning on his son's arm. He is hypertensive and diabetic and has been

struggling with his eyesight recently. He has some hearing impairment with makes communication difficult but his son states that he has been confused for the past 1 year. His main complaint is that he started vomiting bright red blood this morning. This is the first episode. His vital signs are as follows: BP=150/84mmHg, HR=90bpm, RR=12bpm, HGT=4,9mmol/l, Temp= 36,5^{O}C.

5. Mrs E is a 40 year old female who walks in, assisted by her son, using crutches. She states that she injured her right hip 3 days ago after falling from 2 steps. She has had 3 hip replacements, with the first one being at the age of 15 years. She is very concerned that she has sustained an injury to her fragile hip. There is no obvious limb shortening or rotation. Her vital signs are as follows: BP=135/80mmHg, HR=74bpm, RR=12bpm, HGT=4,5mmol/l, Temp=36,8^{O}C.

APPENDIX 3 Post-test questionnaire for research participants

The purpose of this questionnaire is providing baseline demographics of the study participants and to evaluate your experience of the OSCE test you have just completed.

The questionnaire will remain anonymous.

Please fill it in honestly.

Please fill in the required information below and check the appropriate boxes for the questions that follow.

1. **Age:**
2. **Working experience/working years:**
3. **Job title:**
4. **Do you have a hearing impairment?**
   - ☐ Yes
   - ☐ No
   - ☐ Don't know
5. **How do you consider your hearing function:**
   - ☐ Very good
   - ☐ Good
   - ☐ Normal
   - ☐ Bad
   - ☐ Very bad
6. **Thinking about noise in general: Do you consider yourself:**
   - ☐ Not at all sensitive to noise
   - ☐ Somewhat sensitive to noise
   - ☐ Rather sensitive to noise
   - ☐ Very sensitive to noise

7. **On a scale of 1-5 how noisy would you rate your work environment to be:**

   ☐ 1 = Very Quiet

   ☐ 2 = Quiet

   ☐ 3 = Occasionally noisy

   ☐ 4 = Noisy

   ☐ 5 = Excessively noisy

8. **Thinking about the last 6 months spent in your work environment, how much does noise bother, disturb or annoy you?**

   ☐ not at all

   ☐ slightly

   ☐ moderately

   ☐ very

   ☐ extremely

Circle the number that most closely matches your experience during the OSCE test you have just completed.

Question	Not at all	Somewhat	Rather	Very	Extremely
Did you during the OSCE test experience:					
1. Tiredness					
2. Lack of concentration					
3. Headache					
4. Irritation					
5. Confusion					
6. Being out of control					
7. Pressure					
8. Physical Distress					

How did the environmental conditions during the OSCE test affect you?	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
9. The task was made more difficult due to the light conditions					
10. The task was made more difficult due to the noise					
In the following we would like to know more in detail on how the environmental conditions affected your performance during the OSCE test.	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
11. Noise distracted me in the way that I had to start thinking all over again					
12. Noise made the ECG interpretation more difficult					
13. Noise made the drug calculations more difficult					
14. Noise made the data interpretation more difficult					
15. Noise made demanding judgements impossible					

16. Did you do your best during the test? Yes / No

    If No, why not?

    _____
    _____
    _____
    _____
    _____

17. Please comment on any other differences you experienced during the OSCE test while it was noisy compared to when it was quiet.

    _____
    _____
    _____
    _____
    _____

Thank you for taking the time to fill in the questionnaire!