The Effects of Aircraft Noise on Children's Memory and Attention

Phillip Louw (573103)

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Declaration

I hereby declare that this research report is my own independent work, and has not been presented for any other degree at any other academic institution, or published in any form.

It is submitted in partial fulfilment of the requirements for the degree of Masters of Arts in Community-Based Counselling Psychology by Coursework and Research Report at the University of the Witwatersrand, Johannesburg.

Phillip Louw
(573103)

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Abstract

Children have been shown to be particularly vulnerable to the effects of chronic exposure to noise and also aircraft noise. Children attending schools in the vicinity of airports have shown cognitive impairments in reading comprehension, different aspects of memory and attention. This cross-sectional study forms part of a larger longitudinal study conducted at schools in the vicinity of an airport in Durban, South Africa, that was decommissioned and moved. The aim was to investigate the effects of chronic exposure to aircraft noise on children's memory and attention before the moving of the airport. A purposive sample of 834 grade 5 and 6 learners from 5 schools in noisy and quiet areas near the airport were assessed on aspects of episodic memory, working memory, prospective memory and attention with standardised tests in a classroom context. Performance on working memory and one aspect of episodic memory was significantly better in the group exposed to noise. Prospective memory functioning was significantly better in the quiet group. These results, which to some extent unexpected, may prove important in understanding the effects of chronic noise on different aspects of memory functioning. The results and their implications are discussed in relation to previous studies and theories on the effects of noise on memory functioning.

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Chapter 1: Literature Review

Relay of auditory information, whether spoken conversation or information from devices like radios and televisions, is both important and a constant in our daily lives and unwanted sound (noise) can disrupt this flow of information. Noise can take on many forms, where road traffic, railroad traffic and air traffic are some of the major culprits in our day-to-day lives. Apart from disrupting the flow of auditory information through distraction or annoyance, chronic exposure to noise can have adverse effects on physical and mental health (Berglund, Lindvall & Schwela, 1999). Noise pollution has been implicated in various health risks in adults and children ranging from hearing impairment, high blood pressure, ischemic heart disease, annoyance, sleep disturbance and reduced school performance (Passchier-Vermeer & Passchier, 2000). Chronic exposure to aircraft noise has been shown to increase blood pressure, increase heart rate in children, disturb sleep and increase the risk for myocardial infarction (heart attacks) in males (Babish, Beule, Schust, Kersten & Ising, 2005; Evans, Lercher, Meis, Ising & Kofler, 2001; Stansfeld & Matheson, 2003).

Children seem to have a reduced capacity to deal with the negative effects of noise compared to adults (Berglund et al., 1999). Chronic exposure to aircraft noise has been implicated in the lowering of motivation and increase in learned helplessness in children (Berglund et al., 1999; Cohen, Evans, Krantz & Stokols, 1980). Annoyance and irritability are also higher in children exposed to chronic aircraft noise when compared to adults (Berglund et al., 1999; Passchier-Vermeer & Passchier, 2000).

The most notable and most researched effect of chronic exposure to aircraft noise in children is a reduction in certain aspects of cognitive functioning. There are very clear deficits in reading ability and in reading comprehension of children chronically exposed to aircraft noise (Clark, et al., 2005; Evans & Maxwell, 1997; Green, Pasternack & Shore, 1982). With regard to the effects on memory and attention, the findings are less clear cut, however. A study by Smith (1991) showed that chronic noise exposure negatively impacts on children's attention. Other studies by Haines et al. (2001a) and Stansfeld et al. (2005) showed on the other hand no significant deficit in attention when compared to children not exposed to chronic aircraft noise. Long-term episodic memory appears to be affected in children exposed to chronic aircraft noise (Boman, 2004; Boman, Enmarker & Hygge, 2005; Evans, Hygge & Bullinger, 1995; Matheson, Stansfeld & Haines, 2003; Stansfeld et al., 2005) and slight deficits in working memory have been found (Evans et al., 1995; Hygge, Evans & Bullinger, 2002).

This study was conducted in an attempt to resolve the contradictory findings mentioned above will add to the existing body of knowledge on the subject. The main aim of this study was to compare the memory functioning of noise exposed and non-noise exposed children. The noise in this case was chronic exposure to aircraft noise. It aimed to contribute to the theoretical implications of how noise impacts on memory functioning. The results of this study can also inform local governments when planning airports and contribute to policy formation.

The section that follows considers memory and attention from a theoretical perspective, including how noise might impact memory functioning and attention. It will also review findings from previous research on noise and memory, conducted both in the laboratory, as well as field studies.

Noise

Noise can be defined as unwanted sound. Environmental noise in the form of road traffic, air traffic, railroad traffic and the rumblings of a mechanical engine are largely a modern phenomenon (Coats, 2004; Goines & Hagler, 2007). Prior to the twentieth century, sources of unwanted sound or noise were vastly different to what they are today. Thinking back to a nineteenth century environment, the sounds a villager would hear would include the "ringing of the hammer on the anvil, the heavy thud of the wooden mallet wielded by the cartwright, the insistent presence of bells and the whinny of horses", which is vastly different to what the city experience is like today (Coats, 2004, p. 638). Modern noise includes the addition of the engine, which accounts for road traffic, railroad traffic and aircraft noise. Modern noise is also a great deal more difficult to escape from as its sources are widespread and continue to spread at a rapid pace due to rapid population growth and urbanisation. Environmental noise pollution can be regarded as a form of air pollution and can be more serious and detrimental to health than other types of air pollution as the ability to control or regulate it seems almost impossible because there is virtually no escape from it and its chronic nature (Goines & Hagler, 2007). Environmental noise poses serious threats to public health just as other forms of air pollution and can include health problems such as heart problems, increased blood pressure, decreased cognitive performance and noise annoyance that are mediated by a loss of sleep as well as loss of concentration (Goines & Hagler, 2007; Stansfeld & Matheson, 2003). Environmental noise has been described as a “modern plague" (Goines & Hagler, 2007, p. 287) or a form of “sound imperialism” (Coats, 2004, p. 640).

A major contributor to environmental noise is aircraft noise. Aircraft noise as a specific type of environmental noise poses additional problems to other forms of transport traffic noise. Due to aircraft noise being more variable in frequency and of a higher amplitude than other environmental noise, such as railway noise or road traffic noise, it may pose an even greater risk to the health of individuals exposed to it, especially in the case of children (Cohen et al., 1980; Haines, Stansfeld, Job, Berglund & Head, 2001b). Falzone (1999) points out that although there have been laws and legislation in the United States as early as 1972 to combat the effects of aircraft noise through the regulation of airports and aircraft flight paths, little is done to implement these laws and legislation. In South Africa as well, population growth and growth of major cities have meant that airports that used to be outside of the city have in time become part of the city and urban areas around the airports have developed (Van der Merwe & Von Holdt, 2005).

One of the areas of cognitive functioning that would likely be most affected by noise is memory, although existing research findings are inconsistent. The following section will consider memory from a theoretical perspective.

Memory

Discourses around memory have been present for centuries and are evident in early philosophical schools of thought. The study of memory, however, only really started to emerge in the early twentieth century (Baddeley, Eysenck & Anderson, 2009; Bower, 2000; Squire, 2004). Initially the main discourse around memory centered on philosophical understanding but this changed in the early twentieth century where the focus shifted to a more scientific understanding. Herman Ebbinghaus was the first person who studied memory experimentally and this was also the beginning of the study of memory in cognitive psychology (Baddeley et al., 2009). The study of memory evolved as the field started to become subdivided according to the differing theories of memory that developed. Newer and more advanced methods of studying memory also contributed to the knowledge base (Baddeley, 2003b; Squire, 2004). Before discussing memory as a construct and exploring its subcategories, an attempt will be made to define it.

Memory is notoriously difficult to define since the term is used so generally in everyday life and is used to describe a number of different phenomena. How memory is defined would also largely depend on the function that the definition would serve. Scientists in the biological field would define memory differently from cognitive psychologists (Baddeley et al., 2009; Bower, 2000). Generally, memory could be defined as the neuro-cognitive ability to encode, store and retrieve information (both verbal-auditory and visual-spatial). In the biological sciences, the focus would be on the electrophysiological and neurochemical processes and pathways whereby information is stored and retrieved, while the focus in psychology is rather on the psychological level where human behaviour on an interpersonal and social level is used to understand the underlying physiological processes (Baddeley et al., 2009). The two fields differ in terms of focus but ultimately try to describe the same phenomena.

One of the continuing main points of conflict among those who study and theorise about memory was whether it could be viewed as a unitary construct or whether it is made up of many different, related, structures (Baddeley et al., 2009; Squire, 2004). During the 1960's it became widely accepted that memory did not refer to a singular entity but rather to two, three or more systems. Atkinson and Shiffrin (1968, as cited in Baddeley et al., 2009) proposed the modal model of memory that was based on an information-processing approach. The modal model posited that information from the environment is taken in or encoded through sensory memory, moves through short-term memory and then passes to long-term memory (Baddeley, 1999; Baddeley et al., 2009). According to Baddeley et al. (2009) the question around the number of memory systems remains controversial even today and even those who agree that there are multiple memory systems, hold differing views on what those specific memory systems are and how they are related.

One view of the multiple systems of memory consists of dividing memory into long-term memory and working memory. Long-term memory can be further divided into explicit and implicit memory where explicit memory comprises episodic and semantic memory (Baddeley et al., 2009). Working memory, of which short-term memory is a component, consists of the phonological loop, visuo-spatial sketchpad, the central executive and episodic buffer (Baddeley, 2003b). Further, prospective memory can be viewed as a form of long-term memory where a distinction is made between prospective and retrospective long-term memory (McDaniel & Einstein, 2000; Roediger, 1996). For the purpose of this study, this view of the multiple memory systems will be used. Each of these types of memory is described below.

Episodic memory.

Episodic and semantic memory are both forms of explicit long-term memory and share some characteristics, of which the most important is that they are both accessible to consciousness. Semantic memory can be defined as knowledge about the world and includes the knowledge of the meaning of words, the working of society and general knowledge of the world that is sometimes viewed as “inherent”. Episodic memory is defined as knowledge of specific episodes or events in one’s life (Baddeley et al., 2009; Tulving, 1993). Knowledge can be stored or registered in both semantic and episodic memory. There is still some argument around the validity of separating the two as distinctly different since semantic memories were once episodic memories where the episodic details have faded (Tulving, 1993). Evidence for semantic and episodic memory being distinct memory systems are twofold. Firstly, Tulving (1993) makes the distinction between the two memory systems based on the use of conscious awareness in the act of information retrieval. Episodic memory makes use of conscious awareness when information is retrieved whereas with semantic memory, knowledge is often more “inherent” and general. Semantic memories cannot be tied to a particular event and often comes without a conscious feeling of remembering. Secondly, neuroimaging research has shown differences in the use of brain regions when episodic memory or semantic memory is called upon (Baddeley et al., 2009).

Episodic memory involves the encoding, storage and retrieval of specific events or experiences. Personal experiences in your past can be remembered but not only that, we are able to re-experience the event in the act of remembering. This is what is unique to episodic memory: the role that conscious awareness plays in remembering. In episodic memory, the act of remembering a personally experienced event is accompanied by a conscious reexperiencing of the event. This is called "mental time-travel" (Baddeley et al., 2009, p. 93). Events are not merely remembered as loose facts or pieces of information but are ordered in a meaningful way. Episodic memory therefore calls upon a certain kind of "mental filing system" whereby events can be distinguished from each other. This would require three things: firstly a way to encode information in a manner that would make it distinguishable from other events; secondly storing the event in a durable form and lastly a way to search the episodic memory in order to retrieve information about specific events (Baddeley et al., 2009). Episodic memory achieves these three criteria by using constructs called schemas (Baddeley, 1999).

Schemas can be understood as frameworks through which we make sense of and understand our world. The concept of schemas was first used in developmental psychology by Jean Piaget who proposed that children use schemas to make sense of and acquire knowledge of the world. This includes knowledge about "how the world works" (semantic memory) as well as knowledge about previous events. Episodic memories then rely on the schemas to makes sense of events and make meaning of events in order to encode and store them. Episodic memory not only encodes, stores and retrieves information about events that the person has personally experienced, but also stores information about stories read or heard from others. Therefore, when a story is read, the information is stored using existing knowledge represented by schemas. The story is evaluated and interpreted by our own previous experiences. When remembering a story, one of the first things recalled is the attitude or emotional response towards the story. Baddeley (1999) argues that recall is driven and shaped by the attitude toward and emotional investment in the particular story. Motivation to learn is of paramount importance in the ability to store information in episodic memory (Baddeley et al., 2009).

In order for information to be stored as episodic or semantic memories, it must first be processed in working memory. In the section that follows, working memory will be discussed using the multi-component model of working memory (Baddeley, 2003b). The different components of working memory will be described as well as how working memory is connected to episodic memory.

Working memory.

Working memory will be discussed using the multi-component model of working memory of Baddeley (2003b) developed from the three-component model of working memory of Baddeley and Hitch (1974). This model is preferred to other models of working memory (Cowan, 1999, 1998) because of the considerable research, including neuroimaging studies, that support it (Baddeley, 2003b). Working memory is seen as a system that functions as an interface between sensory perception and long-term memory. The multi-component working memory model of Baddeley and Hitch (1974), is comprised of a control system, namely the central executive and two slave systems, namely the phonological loop and the visuospatial sketchpad.

The phonological loop can store visual and auditory input although its main function is to store auditory information. For auditory input, the phonological loop comprises a phonological store that can store memory traces for a few seconds and an articulatory rehearsal process that can be likened to sub-vocal (inner) speech. For visual input there are visual analysis and short-term storage processes as well as recoding of visual material to verbal information that then can enter the phonological short-term store through the articulatory rehearsal process. There are three phenomena that provided evidence for the phonological loop. They are the phonological similarity effect, word-length effect and articulatory or rehearsal suppression (Baddeley, 2003b; Banbury, Macken, Tremblay & Jones, 2001).

The phonological similarity effect is evident in that similar sounding items are harder to remember in a certain order than dissimilar sounding items, thereby reducing the letter span (or word span) of similar sounding letters or words (Baddeley et al., 2009; Baddeley, 2003b; Baddeley, 1999). This does not, however, apply to words that have similar meaning (Baddeley, 2003b). This is evidence that a phonological rehearsal process is at work which is interfered with if words sound similar to each other. The word-length effect refers to the phenomenon that longer words are more difficult to remember. Interpreting the word-length effect with the use of the phonological loop is simple. As words get longer, the rehearsal process of the phonological loop gets slower as less words can be rehearsed before they decay. Therefore the longer the words, the less “space” there is for them to be rehearsed in the phonological loop. A third source of evidence for the phonological loop is the negative impact of irrelevant sound effects on immediate recall. This is known as articulatory suppression, which interferes with the phonological loop's ability to store information as some of the loop's storage gets taken up by the irrelevant words. The effect is not limited to speech or music, but can also be produced by variables tones (Baddeley, 2003b).

The function of the phonological loop seems to have evolved into a system for the acquisition of language and its use in adults and children has been a good indicator for the ability to learn a new language (Baddeley, 2003a, 2003b). Evidence also for this function of the phonological loop has been gathered from patients who had functional deficits in their phonological loop. Language acquisition in such patients was severely affected and learning of novel words that could not be based on known words did not occur (Baddeley et al., 2009; Baddeley, 2003a).

The next component of working memory to be discussed is the visuospatial sketchpad. This is the component of working memory responsible for the encoding and storage of visual and spatial information (Baddeley, 2003b).

The visuospatial sketchpad is limited in capacity to about three or four objects (Baddeley, 1999). Objects that are not attended to are not stored in the visuospatial sketchpad and this leads to the phenomenon known as change blindness. Since physical surroundings largely stay constant, it is therefore not necessary for the visuospatial sketchpad to store detailed information about our physical environment. As a result we often do not attend to insignificant changes that occur. Logie (1995, as cited in Baddeley, 2003b) proposed a fractionation of the visuospatial sketchpad like that of the phonological loop. He proposed a two component system with a visual storage system, called the visual cache, and a dynamic retrieval and rehearsal system, called the inner scribe. When this model was originally conceptualised, there was no real distinction made between visual and spatial memory. According to Baddeley (2003b) a clear distinction can in fact be made between visual and spatial memory as illustrated by the use of two tests that assess visual and spatial memory separately. The Corsi block task, that measures spatial span, is significantly more disrupted by spatial than visual interference and the Pattern Span task, that measures visual span, is significantly more disrupted by visual interference than spatial interference. The capacity of the visuospatial sketchpad of storing and manipulating visual and spatial information is a good measure of non-verbal intelligence and is also supported by neuroimaging data which shows different brain regions store visual and spatial information (Baddeley, 2003b).

The central executive functions as the “control centre” of working memory and although this is the most important component of working memory, it is the least understood (Baddeley, 1999, 1996). This control is thought to be divided into two processes. The first process is control of behaviour by habitual patterns and schemas. This is evident in routine behaviour where actions can occur without awareness of the subject like unconscious imitations of body posture or driving a car without consciously thinking through the behaviour. The second process of control is an attentionally limited controller, the supervisory activating system (SAS) originally proposed by Shallice (1988). The SAS intervenes when control by habitual process is insufficient such as in the case of new or complex behaviours. Baddeley (2003b) proposes that the SAS is somewhat of a homunculus of the central executive. Functions of the SAS would need to include the ability to focus, switch and divide attention, to prevent well-learned, automatic responses from happening, plan ahead and also to link working memory to long-term memory.

A major problem with the initial three-component Baddeley and Hitch (1974) model of working memory was that there was no interaction with long-term memory. The initial hypothesis that the central executive was merely and exclusively an attentional controller was challenged by patients with impaired long-term memory but who possessed the ability to remember passages of prose far greater than the capacity of the phonological loop or the visuospatial sketchpad could account for (Baddeley, 2003b, 2000). Secondly, the three-component model did not account for a system where “chunking” of information greater than the capacity of the phonological loop or visuospatial sketchpad could occur. “Chunking” is a process whereby immediate memory span can constitute sentences up to 15 words, in contrast to five or six unrelated words (Baddeley, 2003b). To account for these shortcomings, a fourth component was added to the three existing components, namely the episodic buffer (Baddeley, 2003b; Baddeley, 2000).

The episodic buffer is a limited capacity store of the central executive that arranges information into clusters to form integrated episodes. It is assumed to be under the control of the central executive and available to conscious awareness. The episodic buffer is therefore considered an important component of working memory in that it provides a way for working memory to interact with long-term memory, in addition to the connection it provides between the phonological loop and visuospatial sketchpad. The proposal of an episodic buffer assumes that rather than being simply activated in long-term memory, long-term information is first stored in a temporary, limited capacity store. With the episodic buffer as a part of working memory it further assumes that working memory can manipulate representations of information and that therefore storage and retrieval of information is a passive process (Baddeley et al., 2009; Baddeley, 2003b, 2000).

Gathercole and Pickering (2000) refined the Baddeley and Hitch's (1974) working memory model, separating the storage and processing components of working memory. Gathercole and Pickering's (2000) model includes short-term memory that is domain-specific, comprising verbal and visuospatial storage components and working memory that is domain-general, comprising a composite of verbal and visuospatial processing components. Alloway, Gathercole and Pickering (2006) found that working memory tasks rely heavily on executive functioning whereas simple storage tasks do not. This provides further evidence for Gathercole and Pickering's (2000) model. This model is functionally similar to the reconceptualised multi-component model of working memory proposed by Baddeley (2003b). The multi-component model contains "short-term memory" within the working memory framework since short-term memory is seen as the "static" component wherein storage takes place.

Once information has been processed in working memory it may be transferred to long-term memory. As discussed, long-term memory comprises several different processes of which prospective memory is one. In the section that follows, prospective memory will be considered. Prospective memory is a form of long-term memory that is very important to everyday functioning in the forming of intentions and the retrieval of those intentions at the appropriate time.

Prospective memory.

Prospective memory involves forming intentions about the future and the retrieval of those intentions in order to realise them at the appropriate time (McDaniel & Einstein, 2000; Roediger, 1996; Smith, 2003). It is therefore extremely important for everyday functioning as there are numerous tasks during an average day that require this type of memory. Tasks such as remembering to buy bread when one comes home from work, remembering to give someone a message when you see them or remembering to do something at a specific time would all require prospective memory (McDaniel & Einstein, 2000; Macan, Gibson & Cunningham, 2010; Roediger, 1996; Smith, 2003). Prospective memory tasks are tasks, or intentions formed about tasks, that have to be kept in mind while doing other tasks and are different to retrospective memory tasks in that there is no explicit command to remember or retrieve the intention (McDaniel & Einstein, 2000; Roediger, 1996). Smith (2003) indicated two broad categories or types of prospective memory namely event-based and time-based prospective memory. Time-based prospective memory refers to when there is an intention to remember something at a certain point in time and event-based prospective memory is an intention to remember something when a certain event occurs in the environment. Since prospective memory tasks requires that the memory or intention be retrieved without an explicit command or request for retrieval. The importance of the intention also seems to impact on whether the intention is later retrieved and acted upon. The greater the importance of the intention, the greater the likelihood that the intention will be retrieved and carried out (Ellis, 1996).

McDaniel and Einstein (2000) posited two processes or ways that prospective memory could achieve such retrieval. These two processes are strategic monitoring of the environment and automatic processes and will be discussed below.

The strategic monitoring process refers to a voluntary process of switching attention from an ongoing activity to the prospective memory task when it needs to realised by continually monitoring the environment for cues related to the prospective memory task. This process would be mediated by an executive attentional controller or system also called the supervisory activating system (SAS, a component of the central executive of working memory, discussed earlier). The SAS may strategically monitor the environment in two ways. Firstly, some of the resources of the executive unit may be allocated to continually monitor the environment for the target cue related to the prospective memory task or secondly, the SAS may bring the intention into conscious awareness on a periodical basis in order to “maintain the activation of the cue-intention association” in order for it to be readily available when the target cue should be encountered (McDaniel and Einstein, 2000, p. 129). Evidence for this process was provided by Smith (2003) where prospective memory tasks were found to affect the performance on ongoing activities. Adult participants in a study who had embedded prospective memory tasks within other memory tasks showed longer response times on non-prospective memory tasks when compared to participants who only had to do non-prospective memory tasks (Smith, 2003). This provides evidence for the use of capacity through strategic monitoring in prospective memory tasks.

The second process described by McDaniel and Einstein (2000) is an automatic process. Retrieval of a delayed intention will happen almost automatically as a result of encountering the target cue for the intention. According to McDaniel and Einstein (2000, p. 129) “this process could be supported by an involuntary automatic associative memory system that delivers to consciousness information previously associated with attended environmental stimuli”. This means that there will be conscious recollection of an intention when the target cue is encountered and interacts with a memory trace of the intention. Whether or not the intention is recalled would largely depend on the strength of the target cue and its ability to produce that interaction. Therefore according to this view, event-based prospective memory would not make use of strategic monitoring of the environment since the encounter with the target cue would produce an automatic process whereby the intention would be retrieved (McDaniel & Einstein, 2000).

McDaniel and Einstein (2000) however state that it is possible to have both strategic monitoring and automatic processing involved in prospective memory tasks based on the situation and type of task. These two processes may even work interactively on the same prospective memory task. These two processes were incorporated into a framework called the multi-process framework for prospective memory (McDaniel and Einstein, 2000). Evidence from neuroimaging studies support the multi-process framework for prospective memory by showing that different brain regions are involved in sustained processes such as strategic monitoring and transient processes such as automatic processes during prospective memory tasks (Gordon, Shelton, Bugg, McDaniel & Head, 2011; Reynolds, West & Braver, 2009). Neuroimaging studies have also provided evidence that prospective memory is structurally different to other memory systems. Specific regions have been found that related to prospective memory tasks and these findings have been replicated by other studies as well (Burgess, Gonen-Yaacovi & Volle, 2011; Gordon et al., 2011; Reynolds et al., 2009).

Ellis (1996, p. 2) posited five different phases of a prospective memory task. The first phase includes the “formation and the coding of an intention or action”. This phase would also stipulate the specifics of the intention such as the action to be done and the time or cue necessary for the prompting of the intended action. The second phase constitutes the “retention interval”; that is the time between the formation or encoding of the intention and the performance interval. The third phase constitutes the “performance interval”; that is the time or “period when the action should be retrieved”. The fourth phase is when the intended action is initiated and executed and the fifth and final phase is when the outcome is evaluated.

Attention

Attention is key to all cognitive processes, particularly memory, since it is very difficult to remember that which was not attended to (Banbury et al., 2001). The control of attentional processes has also been linked to the central executive of working memory (Baddeley, 2003b). Also, the attentional switching that is seen in prospective memory tasks points to the importance of attention in both working memory and prospective memory. Therefore visual attention was also evaluated as part of this study. The type of attention that was studied in this study was sustained visual attention through the use of an adapted version of the Toulouse Pieron Test (Toulouse & Pieron, 1986). Attention will be discussed based on the work of two sets of authors. Firstly, work done by Nakayama and Mackeben (1989) on sustained and transient attention is discussed and linked to memory. Secondly, the feature-integration theory of attention by Treisman and Gelade (1980) is considered.

Nakayama and Mackeben (1989) argued for two types of visual attention, namely sustained and transient attention. Sustained attention was assessed in subjects by providing them with an array with a fixed cue (fixed in position and it lasted the whole time) in the array while they needed to search for an “odd one out” among the shapes. It also included two levels of difficulty, with the odd one either differing only in orientation or in orientation and colour. Sustained attention was associated with higher-order (or “top-down”) processing and was found to be under voluntary control. Transient attention was assessed in subjects by providing them with the same array as with sustained attention but with the cue provided not fixed in position or time. Transient attention was associated with lower-order (or “bottom-up”) processing and was not under voluntary control (Nakayama and Mackeben, 1989).

The SAS of the central executive is an attentional-controlling system (Baddeley, 2003b). It is in control of the ability to focus, switch and divide attention. It can be postulated that a disruption in this ability to sustain and switch attention may indirectly point to a disruption of the SAS. This would then lead to a decrease in the capacity of working memory as well as prospective memory. It would then seem that the ability to sustain and switch attention would require both sustained and transient attention as both voluntary and involuntary cognitive processes play a part in working memory and prospective memory.

Attention and memory seem to be related in different ways and mediated by various factors as well. Baddeley (1999) argued that motivation to learn and attention have an impact on each other. The amount of learning that will take place depends on the amount of attention that the child pays to that which is being taught. Attention is dependent on motivation since the more interested a child is, the higher the motivation to learn and then the higher the amount of attention paid. It would then seem that if either motivation or attention is disrupted, it could negatively influence learning.

Treisman and Gelade (1980) posited a theory of attention called the feature-integration theory of attention. This theory states that different things in the environment can be attended to fast in parallel but that this parallel processing of features (such as colour, orientation or movement) is not necessarily correctly combined (for example the colour and shape may not be matched). For a correct matching of features, serial processing is necessary, which is a slower process. This serial processing combines all the relevant features of an object at a particular location in order for the object to be correctly identified. Unattended objects in the background that are not the focus of attention can be identified through parallel processing as long as they are not too similar to their surrounding environment or if there is prior knowledge of an object (for instance the sun is yellow and the sky is blue).

There are two distinct stages involved in the correct perception of an object (Treisman, 1988; Treisman & Gelade, 1980). The first stage is the pre-attentive stage and involves the analysing of the different aspects of an object. The shape, colour, orientation and movement of the object are analysed in different areas of the brain. This stage takes place even before there is awareness of attending to the object. The second stage involves the perception of an object that is the focus of attention. The different features that were analysed in the first pre-attentive stage is then combined to make an integrated whole. If the object is unknown, all the features need to be integrated, but if the object is known (from prior knowledge), only a certain amount of features need to be attended to until the object is recognised. This led Treisman (1988) to distinguish between two types of visual search, namely feature search and conjunction search. Feature search is done quickly and pre-attentively for objects defined only by colour, shape or orientation. Conjunction search is a much slower process and makes use of serial processing. This type of search is used when there is more than one feature (a conjunction of two or more features) that comprises an object. Conjunction search also requires conscious attention (Treisman, 1988; Treisman & Gelade, 1980).

Treisman and Gelade (1980) conducted a range of experiments using different tasks involving attentional processes to test their feature-integration theory. Even though the results of these experiments could be explained in more than one way, they posited that since all of the results supported this theory of attention it is an appropriate way to conceptualise it.

This concludes the theoretical understanding of memory and attention. Long-term memory was viewed from two vantage points. Firstly, long-term memory was discussed with reference to episodic memory and compared to semantic memory. Long-term memory was also discussed with reference to prospective memory where other memory systems are seen as retrospective memory. Working memory was discussed using the multi-component working memory model of Baddeley (2003) and lastly attention was discussed considering the work done by Nakayama and Mackeben (1989) as well as the feature-integration theory of Treisman and Gelade (1980).

The following sections consider the research available on the non-auditory and auditory effects of noise on people. Findings from studies that investigated a wide range of possible effects of noise on health and cognition are presented.

Research on Effects of Noise

Environmental noise exposure has been linked to negative effects in both adults and children with regard to sleep disturbance (Fyhri & Aasvang, 2010; Godlee, 1992; Muzet, 2007; Passchier & Passchier-Vermeer, 2000; Stansfeld & Matheson, 2003), increases in blood pressure and cardiovascular problems (Evans, Bullinger & Hygge, 1998; Fyhri & Aasvang, 2010; Godlee, 1992; Passchier & Passchier-Vermeer, 2000; Paunovic, Stansfeld, Clark & Belojevic, 2011; Rosenlund, Berglind, Pershagen, Jarup & Bluhn, 2001; Stansfeld & Matheson, 2003; Van Kempen et al., 2002; Van Kempen et al., 2006; Weinhold, 2002), physiological (endocrine) responses (Evans et al., 1998; Fyhri & Aasvang, 2010; Haines et al., 2001a; Passchier & Passchier-Vermeer, 2000; Selander et al., 2009), annoyance (Bjork et al., 2006; Evans et al., 1995; Godlee, 1992; Passchier & Passchier-Vermeer, 2000; Stansfeld & Matheson, 2003) and decreased performance (Dockrell & Shield, 2006; Ljungberg & Neely, 2007; Szalma & Hancock, 2011). In children specifically, exposure to environmental noise has been linked to decreases in motivation and learned helplessness (Cohen et al., 1980; Evans et al., 1995; Evans & Stecker, 2004; Passchier & Passchier-Vermeer, 2000; Stansfeld et al., 2005; Stansfeld & Matheson, 2003) as well as cognitive developmental deficits in reading comprehension, memory and attention (Boman, 2004; Boman et al., 2005; Clark, et al., 2005; Evans et al., 1995; Evans & Maxwell, 1997; Green, Pasternack & Shore, 1982; Matheson et al., 2003; Stansfeld et al., 2005).

During epidemiological studies, populations that are studied are assumed to be homogenous. When considering environmental health hazards however, this cannot be assumed. Children are different to adults in the way that they are exposed to and react to the environment (Bearer, 1995a, 1995b). Children are a particularly vulnerable population when exposed to environmental pollutants or stressors (Bearer, 1995a, 1995b; Weiss & Bellinger, 2006). This has also been shown to be the case with exposure to environmental noise and especially aircraft noise (Berglund et al., 1999). Children have been found to react differently to adults when exposed to environmental noise with regard to sleep disturbance (Ohrstrom et al., 2006; Passchier & Passchier-Vermeer, 2000) and cardiovascular disease (Passchier & Passchier-Vermeer, 2000). Children also show some additional symptoms due to environmental noise exposure such as decreased motivation, learned helplessness and cognitive deficits seen in deficits in reading comprehension, decreases in long-term and short-term memory as well as decreases in attention (Stansfeld & Matheson, 2003). Due to children's perceived vulnerability to the non-auditory health risks of exposure to environmental noise and the possible irreversible cognitive deficits inherent in that risk, researchers have been prompted to investigate the effects of environmental noise on children's cognition. Researchers have focused predominantly on reading comprehension, memory and attention (Stansfeld & Matheson, 2003).

A number of studies have focused on the effects of noise on children's cognition, especially reading comprehension, different aspects of memory and attention. Reading comprehension has consistently been found to be negatively affected by noise and also specifically aircraft noise (Clark, et al., 2005; Evans & Maxwell, 1997; Green, Pasternack & Shore, 1982; Haines et al., 2001a; Stansfeld et al., 2005). Two of the main reasons provided for the negative effect of noise on reading comprehension have been the interference of noise with regard to children hearing their teacher in a classroom setting as well as interference with normal classroom learning and therefore interference with language development. Results from studies that explored the effects of noise, generally and aircraft noise specifically, on children's memory have been contradicting (Matheson et al., 2010).

Studies of the effects of noise on memory can vary based on different factors (Hygge, 2003; Matheson et al., 2010). These include the type of memory system studied, the type of test used to measure the specific memory system as well as the complexity and type (verbal or visual) of information to remember, the source of noise (irrelevant sound effects or meaningful sound), the amplitude of the noise used (how loud it is), as well as the frequency of the noise (whether it is chronic or acute). A further factor is whether the study takes place in a laboratory setting or in a naturalistic setting. Usually, naturalistic studies have examined chronic noise exposure and laboratory studies have looked at acute noise exposure (Matheson et al., 2010). As each of these factors can influence the impact of noise on memory in a particular study, it is no wonder that such contradicting results have been found.

Long-term memory, in the form of episodic and semantic memory, is one example of inconsistency in findings. Matheson et al. (2010) and Stansfeld and Matheson (2003) found it to be negatively affected by chronic noise in children, while other studies did not find significant effects (Haines et al., 2001) or even found significant positive effects for episodic memory (Stansfeld et al., 2005). When tested on free recall and cued recall tests, children who were exposed to chronic noise (such as aircraft noise) fared worse than children who lived and schooled in quieter areas (Evans et al., 1995). Some studies found that recognition memory was negatively affected by chronic aircraft noise (Stansfeld et al., 2005; Haines et al., 2001a) but others did not (Haines et al., 2001b). Inconclusive evidence for the effect of chronic aircraft noise on working memory was found with some studies finding no effect (Matheson et al., 2003) and some finding negative effects (Stansfeld et al., 2005). Prospective memory has received little attention to date. One study by Stansfeld et al. (2005) found no effect for chronic aircraft noise on prospective memory.

The current study was a field study, looking at the effects of chronic aircraft noise on children's memory functioning and attention in a school environment. Even though the extraneous variables cannot be controlled in a field study, the ecological validity increases since there is a better approximation of real-life situations. A number of studies similar to the current study was done and the findings are summarised below.

The three most influential and prominent field studies that are similar to the present study are the Munich Airport study (Evans et al., 1995; Evans et al., 1998; Hygge et al., 2002), the West-London Schools study (Haines et al., 2001a; Haines et al., 2001b) and the aircraft and road traffic noise and children's cognition and health (RANCH) study (Stansfeld et al., 2005).

In the Munich Airport study advantage was taken of a naturally occurring event, namely the relocation of a major airport in Munich. This provided an opportunity to study the effects of aircraft noise on children as well as to determine whether these effects remain or disappear when the source of noise is moved (Evans et al., 1995; Evans et al., 1998; Hygge et al., 2002). The total sample size used in the study was 326 children. Two experimental groups were used: one group near the old airport and the second group near the new airport. The control groups were matched to the respective experimental groups with regard to socio-demographic factors. Data were collected in three waves, one before the closure of the airport and two after the closure of the airport. Reading comprehension, episodic memory, working memory, attention and speech perception were tested.

The West-London Schools Study was conducted by Haines et al. (2001a) in areas around Heathrow Airport in London. This study improved on the Munich Airport study (Evans et al., 1995; Evans et al., 1998; Hygge et al., 2002) since a larger number of schools were used and therefore reduced possible biases related to differences in schools. This study, however, used a cross-sectional design as opposed to the longitudinal design of the Munich Airport study (Evans et al., 1995; Evans et al., 1998; Hygge et al., 2002) which limits the strength of the findings but allows for developmental comparisons to be made. The sample consisted of 451 children from 20 schools, 10 of which were located in high aircraft noise areas and 10 in quiter areas. General health outcomes were measured as well as annoyance, reading comprehension, episodic memory and sustained visual attention.

The RANCH study was a cross-national study conducted in England, the Netherlands and Spain (Stansfeld et al., 2005). It improved on both the Munich Airport study (Evans et al., 1995; Evans et al., 1998; Hygge et al., 2002) and the West-London Schools study (Haines et al., 2001a) in that a considerably larger sample size was used, over three countries, making the results more robust. The total sample size was 2844 children from 89 schools in England, Netherlands and Spain near major airports. Health and cognitive outcomes were measured. Cognitive outcomes that were measured were reading comprehension, episodic memory, working memory, prospective memory and sustained attention.

Results from the Munich Airport study (Evans et al., 1995; Evans et al., 1998; Hygge et al., 2002) indicated that reading comprehension and episodic memory were significantly worse in the groups exposed to aircraft noise. No significant effects were found for working memory or attention. They also found that the negative effects disappeared after the closure of the old airport and the negative effects were stronger at Wave 3 than at Wave 2 at the new airport, suggesting a worsening effect over time. The West-London Schools study (Haines et al., 2001a), however, found non-significant results for reading comprehension, episodic memory and sustained attention and only found a significant result for noise annoyance with the noise-exposed group showing greater annoyance with the noise. The RANCH study (Stansfeld et al., 2005) greatly improved on the other two studies in that the exposure-effect relationship of noise and cognitive abilities were investigated. The researchers found a linear exposure-effect association between exposure to aircraft noise and deficits in reading comprehension, episodic memory and increased noise annoyance. No significant effects were found for sustained attention, working memory or self-reported health. The findings from the RANCH study (Stansfeld et al., 2005) are consistent with the findings from the Munich Airport study (Evans et al., 1995; Evans et al., 1998; Hygge et al., 2002) and also the effect for noise annoyance found in the West-London Schools study (Haines et al., 2001a).

Limitations of the West-London Schools study (Haines et al., 2001a) and RANCH study (Stansfeld et al., 2005) were that they were cross-sectional in design whereas the Munich Airport study (Evans et al., 1995; Evans et al., 1998; Hygge et al., 2002) used a longitudinal research design. A strength of both the West-London Schools study (Haines et al., 2001a) and the RANCH study (Stansfeld et al., 2005) was that multilevel modelling was used as analytical technique since the sample sizes were large enough. This allowed the researchers to adjust for the potentially confounding effect of school characteristics on the relationship between noise and performance at the individual level (Haines et al., 2001a; Haines et al., 2001b). A strength of all three studies was that they all matched experimental groups and control groups on socio-demographic factors. None of the studies assessed the children’s hearing or auditory processing abilities with only the Munich Airport study (Evans et al., 1995; Evans et al., 1998; Hygge et al., 2002) including tests of whether the children had normal hearing or not.

The present study draws on the strengths of all three studies mentioned above. It used a longitudinal design (the larger study, RANCH-SA, of which this study forms part, used a longitudinal design), makes use of a large sample size and also matched experimental and control groups on socio-demographic factors. An improvement on the three studies mentioned above is that children's auditory processing abilities and hearing were assessed before taking part in the study.

Hypotheses on the effects of Noise on Memory and Attention

The field studies considered all started with the hypothesis that chronic exposure to road traffic or aircraft noise would impair cognitive performance on academic tasks. The initial hypotheses of why this would be the case ranged from the direct effect of noise on memory functioning such as suppression of the articulatory rehearsal process in working memory to indirect effects such as the mediating effect of loss of sleep or interference with teacher audibility in the classroom (Haines et al., 2001a; Haines et al., 2001b ; Stansfeld et al., 2005; Stansfeld & Matheson, 2003).

This negative effect of noise on different aspects of cognition was not the regular result that was expected. Apart from reading comprehension and noise annoyance that consistently showed significant effects with noise, other aspects of cognition such as different forms of memory and attention did not follow this pattern (Hygge et al., 2002; Stansfeld et al., 2005; Stansfeld & Matheson, 2003). Non-significant results were mostly explained as faults or inaccuracies in measurement or as the effects of variables that may have had a mediating effect on the variables. The role of habituation was considered as a possibility but was not entered into in depth as a meaningful explanation of the results (Stansfeld & Matheson, 2003). Habituation to noise during the day has been studied and found to be a useful way of explaining how exposure to noise can have no significant effect on cognitive performance (Smith, Waters & Jones, 2010).

Disturbance of sleep from nocturnal aircraft and road traffic noise has been given as a possible mediator for possible decreased cognitive performance during the daytime (Basner, 2008; Eberhardt, Strale & Berlin, 1986; Stansfeld & Matheson, 2003). Habituation of sleep to noise has also been investigated in studies and has shown to be possible even after a short amount of time, such as a few days (Kawada et al., 2000). Habituation as a process to explain possible non-significant results of noise on memory and attention is therefore more complex than just the habituation to noise in the day. Habituation of sleep to noise must also be considered as a possible explanation of why significant effects of noise on memory and attention are not consistently seen in studies.

Research Rationale

Chronic aircraft noise is a threat to the physical, emotional and mental health of those who are exposed to it. It has been implicated in disturbance of sleep, increased annoyance, impairments in hearing, elevated blood pressure and increased risk of myocardial infarction (Babish et al., 2005; Evans et al., 2001; Passchier-Vermeer & Passchier, 2000; Stansfeld & Matheson, 2003). Children are seen as a particularly vulnerable population as they have a reduced capacity to deal with the negative effects of chronic exposure to aircraft noise and have not developed effective coping mechanisms of dealing with noise (Berglund et al., 1999). Research suggests that children show a range of cognitive deficits when exposed to chronic aircraft noise. These include impairments in reading comprehension, episodic memory, working memory and sustained attention (Boman, 2004; Boman et al., 2005; Clark, et al., 2005; Evans & Maxwell, 1997; Evans et al., 1995; Green et al, 1982; Matheson et al., 2003; Stansfeld et al., 2005)

The effects of noise go beyond the possibility negatively affecting physical or emotional well-being, it can also impact communities on an economic level. A direct effect of noise around airports and the negative effects thereof would be that property values are lower than in quieter areas. Nelson (2004) did a meta-analysis of the negative relationship between airport noise exposure and property values in the United States and Canada. He found that with increasing noise the property values were between 12 and 15 per cent lower and can be even 20 per cent lower than in quieter neighbourhoods. In Cape Town, the residential areas surrounding the Cape Town International Airport are mostly lower socio-economic status residential areas and this is true for many of the airports in South Africa (Van der Merwe & Holdt, 2005). This would mean that many people living near airports and their children going to schools in the same area are poor and have little resources available, thus making it very difficult to move. Further, these communities will have little bargaining power in terms of their own well-being.

On a practical level, this study can serve to inform local governments of the negative effects of chronic exposure to aircraft noise and result in safety measures being implemented as described in Van der Merwe and Holdt (2005) and Goldschagg (2007) when designing or restoring airports to ensure the safety of those living near airports. On a theoretical level, it will contribute to evidence regarding how chronic noise impacts on memory functioning and attention. Findings on the effects of aircraft noise on episodic memory and attention have been inconsistent and findings on the effects on working and prospective memory have so far been inconclusive. This study was conducted in an attempt to provide greater clarity in this regard.

Chapter 2: Method

This chapter describes the research design, sampling strategy, the measurement instruments and variables measured as well as the ethical considerations made before the study commenced. The broader research aim was to compare the memory functioning of noise exposed and non-noise exposed children. This aim was operationalised as the following research questions:

1. Is there a significant difference between children exposed to high levels of aircraft noise and children in quieter areas in terms of episodic memory functioning?
2. Is there a significant difference between children exposed to high levels of aircraft noise and children in quieter areas in terms of working memory functioning?
3. Is there a significant difference between children exposed to high levels of aircraft noise and children in quieter areas in terms of prospective memory functioning?
4. Is there a significant difference between children exposed to high levels of aircraft noise and children in quieter areas in terms of sustained visual attention functioning?

Research design

Archival data was used from a study that made use of a quantitative, non-experimental, cross-sectional, between-subjects, ex-post facto research design. An ex-post facto (after the fact) research design was used as there was no manipulation of variables and no random assignment was done (Graziano & Raulin, 2010). The study was done on a naturally occurring event and therefore the researcher did not have control over and could not manipulate the independent variables of interest.

Sample

The experimental group consisted of learners from the fifth and sixth grade (ages 10 to 12 years) in two primary schools exposed to relatively high aircraft noise (63-69 decibels). The control group consisted of learners from the fifth and sixth grade (ages 10 to 12 years) in three primary schools in relatively low aircraft noise areas (53-54 decibels). The experimental group schools were chosen first based on where the noise levels are the highest (as close to directly beneath the flight paths as possible) and was subject to approval by the principals of the schools. The control group schools were then chosen where the noise levels were the lowest within a five kilometre radius of the experimental group schools, not near to any large roads and also subject to the approval of the relevant principals. The experimental and control groups were matched on several socio-demographic characteristics (language, parental education level and occupation).

Non-probability, purposive sampling was used to obtain the participants. A minimum of two years residence in the area, normal hearing (as perceived by parents and teachers) and an absence of learning difficulties, auditory and attentional problems were prerequisites to partake in the study. Approximately 820 learners participated in the study. In Table 1 the demographics of the sample are displayed.

Table 1

Participant Demographics

	Group	
Characteristic	Experimental[a] (*n* = 437)	Control[b] (*n* = 397)
Mean Age (years, months)	11,7	11,9
Grade		
5	190	192
6	247	205
Gender		
Male	195	171
Female	191	179
Main Language		
English	106	114
Other	209	153
Maternal Education		
No Schooling	8	18
Below Grade 12	104	74
Grade 12	91	102
Higher Certificate/ Diploma	89	50
Degree	18	15

[a]Noise-exposed group. [b]Quiet group

The demographics in Table 1 indicate that the two groups are very similar with respect to age, grade and gender. It also seems as if the two groups do not differ much on main language and maternal education. The low response rates for the experimental and control groups on main language (72.1% and 67.3% respectively) and on Maternal Education (70.1% and 65.2%) make it difficult to get a clear picture of these characteristics in the sample.

Data and Measurements

Data from the first wave of data collection of the RANCH-SA study was analysed in the study. This took place prior to the decommissioning of the airport. The measurement instruments that were used in the RANCH-SA study to gather the data that will be used in the proposed study were the following instruments (Appendix G): the Child memory Scale (Cohen, 1997), The Search and Memory Task (Smith & Miles, 1987), the Toulouse Pieron Test (Toulouse & Pieron, 1986) and a measure of prospective memory described below.

Long term memory recall and recognition.

Delayed recall and recognition memory were measured using an adaptation of the Child Memory Scale (Cohen, 1997) also used in the Munich Study. This task measured the delayed recall and recognition of two stories. Two stories were read to the children. Another test was given as an interference task, and thirty minutes later the children were requested to write down again as much as they could recall of the stories in response to specifies questions. This constituted the assessment of recall memory. Recognition of the two stories was then measured by thirty factual questions with “yes” or “no” responses. Two scores were calculated; namely, delayed recall and recognition scores.

Working memory.

In the Search and Memory Task, also known as Letter Detective (Smith & Miles, 1987), children were required to memorise between one and seven letters and then search through lines of jumbled letters for items that match the targets and put a line through them. The test comprised two practice trials followed by seven test trials. In the initial trials in which there were few target letters to be remembered, the test essentially assessed attention. However, as the number of target letters increases the test becomes one of working memory. This task yielded three scores, namely, the hits (correctly identified target letters), false positives (non-target items inadvertently identified as targets), and a direct score (obtained by subtracting the false positives from the hits).

Prospective memory.

Before the two 45 minute test sessions, the learners were told to write down their initials at three predetermined points during the tests. This tested their prospective memory.

Attention.

An adapted version of the Toulouse Pieron Test (Toulouse & Pieron, 1986), which measures sustained visual attention based on simple visual figures (small spiky squares), was used. The children were required to identify exemplars of two target figures which were randomly distributed within a large set of similar, but different, figures. This test yielded four scores, namely, the hits (correctly identified target), omissions (target items which were missed or omitted), false positives (non-target items erroneously identified as targets), and direct score (obtained by subtracting the false positives and misses from the hits)

Figure Analogies.

Given that intelligence is often regarded as a potential confounding variable, especially for reading ability, the Figure Analogies subtest of the Quantitative battery for Cognitive Abilities Test (3rd Edition) was also administered. The Figure Analogies test (also known as Matching Mate) presents figural analogies of the type ‘A→B: C→___’. This test measured both inductive reasoning because an inference is made regarding the relationship between the first pair, as well as deductive reasoning in the sense that the inferred relationship is applied to the choice of an answer. It also assessed visualization given that the child had to imagine the effect of postulated transformations upon the stimuli. It comprised twenty questions. It is reported to have good validity and a Kuder-Richardson reliability coefficient of 0.91.

Pilot study.

Given that instruments that were utilised in the study were not standardised for the South African population, a pilot study was conducted at two government schools in Kwa-Zulu Natal province to investigate the validity and reliability of these instruments, as well as to compare cognitive performance (reading comprehension, working memory, intelligence and attention) of 174 learners aged 9-13 years attending school in a noise exposed area (experimental group) and those from a relatively quieter area (control group). Moderate to high internal reliability coefficients were found for each of the measured constructs as follows, 0.61 (recognition memory), 0.75 (attention), 0.65 (intelligence), 0.59 (working memory), 0.71 (reading comprehension). Paired t-tests and Analyses of Covariance (ANCOVAs) were used to compare the experimental and control groups on reading comprehension, intelligence and on a subtest of sustained visual attention. When the effects of intellectual functioning were controlled for, significant differences were yielded between the two groups on sustained visual attention ($F = 5.86$; $p<.05$) and reading comprehension ($F = 40.98$; $p<.01$), in favour of the control group.

Further results related to the reliability and item analysis difficulty of data from the pilot study are reported in detail in a Masters research report (Van Der Merwe, 2010). On the basis of these findings, minor insignificant differences were found from the original instruments, as a result, no adaptation of the instruments were made. Learners who participated in the pilot study did not take part in the larger study.

Procedure

This study used data from the greater RANCH-SA study. Data collection took place before the closure of the Durban International Airport. The procedure used to capture the data that was used in this study was as follows: At each of the two experimental schools and the three control schools the learners involved were administered a series tests in two 45 minute sessions in a group setting. The following tests were administered: the Suffolk Reading Scale (Hagley, 1987), the Child Memory Scale (Cohen, 1997), the Toulouse Pieron Test (Toulouse & Pieron, 1986), the Search and Memory Task (Smith & Miles, 1987), the Figure Analogies subtest of the Cognitive Abilities Test and the learners was also to sign their initials in the margin at three predetermined points to test prospective memory.

As the proposed study is interested in cognitive measures of functioning, specifically memory and attention, data that was gathered through the use of the Child Memory Scale (Cohen, 1997), the Toulouse Pieron Test (Toulouse & Pieron, 1986) and the Search and Memory Task (Smith & Miles, 1987) will be analysed.

Data analysis

The procedures used to analyse the different aspects of memory and attention are given in detail in the next chapter, results.

Ethical Considerations

Informed consent was obtained from parents and teachers and informed assent obtained from learners prior to data collection. Confidentiality of participants will be assured in that information that may identify participants will not be included in the research report. Participants were made aware of their right to withdraw from the study at any time. Complete anonymity cannot be assured since participants need to be tracked due to the longitudinal nature of the overarching (RANCH-SA) study. Permission to conduct this study at Durban International Airport was obtained from the University of the Witwatersrand (protocol number 2008ECE94 - see Appendix A), the Kwa-Zulu Natal department of Education, principals of the schools, parents of children involved, teachers of classes that were used and the learners involved. Information letters and consent and assent forms were given to the respective parties (Appedices B-F).

Chapter 3: Results

A series of statistical procedures were carried out in order to address the research questions. Firstly, the demographics of the participants are provided. Thereafter, tests for normality were conducted on each variable to consider whether they were fit for parametric analysis. Statistical techniques were then used in order to address the research questions posed. Possible confounding variables were controlled for with regard to significant results and effect sizes for the significant results were calculated.

The response rates on the tests that measured the dependent variables were calculated and are shown in Table 2.

Table 2

Response Rate of Participants

Response Rate (Percentage)	Experimental[a] *(n = 437)*	Control[b] (*n* = 397)
Recognition Memory	379 (86.7%)	348 (87.7%)
Information Recall	349 (79.9%)	347 (87.4%)
Working Memory	381 (87.2%)	349 (87.9%)
Prospective Memory	380 (87.0%)	350 (88.2%)
Attention	343 (78.5%)	315 (79.3%)
Intelligence	356 (81.5%)	352 (88.7%)

Note
[a] Noise-exposed group. [b] Quiet group.

The different response rates on the dependent variables as shown in Table 2 illustrates the complexity of the sample as a whole. This makes it particularly difficult to conduct multivariate statistical techniques on all the dependent variables. When a MANOVA was run with all the above variables (with the exception of Prospective Memory) only n = 301 cases for the experimental group and n = 307 cases for the control group were used. It was therefore deemed more appropriate and would be more precise to run statistical procedures on each variable separately.

It is necessary to ascertain whether or not the variables that are to be analysed are normally distributed in order to know whether parametric or non-parametric tests are to be used in their analysis (Howell, 1997). The means, medians and standard deviations of the dependent variables (separated by group) are given in Table 3. These measures give an indication of the central tendency and variability of the variables.

Table 3

Descriptive Statistics

	n	*M*	*Mdn*	*SD*
Recognition Memory				
Experimental	379	21.84	22.00	3.19
Control	348	21.26	22.00	4.13
Information Recall				
Experimental	349	20.39	20.00	14.29
Control	347	18.65	16.00	14.85
Working Memory[a]				
Experimental	381	15.59	17.00	8.32
Control	349	13.22	15.00	9.62
Prospective Memory				
Experimental	380	1.17	.00	3.57
Control	350	1.61	.00	4.31
Attention[b]				
Experimental	343	60.40	76.00	69.40
Control	315	62.30	72.00	71.97

Note
[a] Excluded n = 8 outliers. [b] Excluded n = 13 outliers

The standard deviations shown in Table 3 reflect the variability and spread of the dependent variables. As the task that measures Attention allows for a negative score, the variability is very large with the standard deviations larger than the means. Recognition

Memory shows the least variability, shown by the fact that its standard deviations are very small when compared to its means.

The variables' normality were assessed using histograms (Refer to Appendix C), measures of central tendency such as means, medians and standard deviations that are given in Table 3 and lastly using Kolmogorov-Smirnov Tests for normality that are reflected in Table 4.

Table 4

Kolmogorov-Smirnov Tests for Normality

	n	*D*-statistic	*p*
Recognition Memory			
Experimental	379	.100	< .001**
Control	348	.090	< .001**
Information Recall			
Experimental	349	.109	< .001**
Control	347	.126	< .001**
Working Memory[a]			
Experimental	381	.100	< .001**
Control	349	.117	< .001**
Prospective Memory			
Experimental	380	.515	< .001**
Control	350	.511	< .001**
Attention[b]			
Experimental	343	.165	< .001**
Control	315	.084	< .001**

Note

[a] Excluded n = 8 outliers. [b] Excluded n = 13 outliers

* $p < .05$. ** $p < .01$

Results of the Kolmogorov-Smirnov Tests, as shown in Table 4, indicate that none of the variables are normally distributed. It must be noted though that the Kolmogorov-Smirnov Test is highly robust and very sensitive to slight deviations from normality, especially when considering distributions with large sample sizes. However, with large sample sizes, normality can be more easily assumed, which is not reflected in this test (Howell, 1997). Consequently, it was decided to assume normality with all the variables, with the exception of Prospective Memory. Therefore parametric statistical techniques were employed in analysing these variables. Analyses of variance (ANOVA's) were used to compare the two groups on the dependent variables. In cases were significant differences were found between the groups, Analyses of covariance (ANCOVA's) were run with intelligence as a covariate and effect sizes (Cohen's *d*) were calculated. The statistical technique used to analyse Prospective Memory will be discussed at a later stage.

The variables that were considered to be normally distributed were then compared according to group (experimental or control) with one-way ANOVA's. The results of this comparison are given in Table 5.

Table 5

Comparison between the groups with one-way ANOVA's

	F	*df*	*p*
Recognition Memory	5.45	725	.020*
Information Recall	2.48	694	.115
Working Memory	12.73	728	< .001**
Attention	.119	656	.730

* $p < .05$. ** $p < .01$

As shown in Table 5, there were significant differences between the experimental and control groups on the variables Recognition Memory $F(2, 725) = 5.45$, $p = .020$ and Working Memory $F(2, 728) = 12.73$, $p < .001$. With both of these variables, the experimental group performed significantly better than the control group.

With the variables that showed a significant difference, intelligence was used as a covariate in ANCOVA's to ascertain whether it has an effect on the significance level of these variables. ANCOVA's were then run on Recognition Memory as well as Working Memory with IQ as a covariate. The results of these analyses are given in Table 6.

Table 6

Comparisons between the groups with adjustment for intelligence

	Unadjusted		Adjusted for Intelligence	
	F	*p*	*F*	*p*
Recognition Memory	5.45	.020*	4.84	.028*
Working Memory	12.73	< .001**	9.22	.002**

* $p < .05$. ** $p < .01$

As can be seen in Table 6, after controlling for the effect of intelligence on the respective variables, there are only slight shifts in their *F*-values as well as their *p* values with Recognition Memory $F(2, 695) = 4.84$, $p = .028$ and Working Memory $F(2, 692) = 9.22$, $p = .002$.

It has become common practice to include effect sizes whenever significant results are found in order to assess the practical meaningfulness of the difference that had been found. Effect size is a measure of the of the size of a difference found between means and is expressed in units of standard deviation (Graziano & Raulin, 2010). Cohen (1992) proposed a measure of effect sizes and stated that effect sizes of .20 are small, .50 are medium, and .80 are large (Thalheimer & Cook, 2002). In Table 7 the effect sizes for Recognition Memory and Working Memory are displayed.

Table 7

Effect sizes for Recognition Memory and Working Memory

Variable	*F*	*p*	*d*
Recognition Memory	4.84	.028*	.172
Working Memory	9.22	.002**	.230

* $p < .05$. ** $p < .01$

The effect sizes that are included in Table 7 for Recognition Memory, d = .172, and Working Memory, d = .230, indicate very small effect sizes in both cases. This suggests that even though significant differences are found between the groups for the respective variables, the practical value of these differences may be limited.

It is possible that noise may interfere with tasks only if the task has a certain degree of cognitive complexity (Van Kempen et al., 2010). Since the task used to measure working memory in this study comprises of seven tasks that are progressively more cognitively complex, it was deemed appropriate to see whether this aforementioned pattern could be discerned. In Table 8, the means for each of the seven tasks that forms part of Letter Detective are given.

Table 8

Means and Standard Deviation of Letter Detective tasks

	Experimental		*Control*	
	M	*SD*	*M*	*SD*
Task 1	5.52	1.47	5.43	1.40
Task 2	4.66	1.45	4.46	1.75
Task 3	3.21	2.03	2.76	2.11
Task 4	1.51	2.22	.92	2.46
Task 5	.33	2.89	-.22	3.07
Task 6	.41	2.85	.32	2.78
Task 7	-.02	3.10	-.41	2.88

As can be seen in Table 8, the mean scores decrease from the first task to the last (with the exception of task 6 and task 7). This may indicate that the tasks get progressively more complex and the participants find the latter tasks more difficult. The standard deviations also increase as the means decrease. This indicates that there is a wider spread in the performance on the tasks as they get more difficult.

One-way ANOVA's were used to determine if there are significant differences in performance between the two groups on the different tasks. The results of the ANOVA's are given in Table 9.

Table 9

Comparison between the groups for Letter Detective tasks

Task	*F*	*df*	*p*
Task 1	.67	726	.413
Task 2	2.79	726	.095
Task 3	8.88	726	.003**
Task 4	11.61	727	.001**
Task 5	6.37	727	.012*
Task 6	.183	727	.669
Task 7	3.059	727	.081

* $p < .05$. ** $p < .01$

Significant differences between the two groups were found for Task 3, $F(2,726) = 8.88$, $p = .003$, Task 4, $F(2, 727) = 11.61$, $p = .001$ and Task 5, $F(2, 727) = 6.37$, $p = .012$. All the differences were in favour of the experimental group. It is interesting to note that there were no significant differences between the groups on the easiest and most difficult tasks.

As earlier mentioned, Prospective Memory could not be assumed to be normally distributed based on inspection of the histograms of its distribution (Refer to Appendix C, Figure 4), descriptive statistics (mean, median and standard deviation) as well as it's Kolmogorov-Smirnov test statistic. Also, after inspection of the distribution of Prospective Memory (Figure 4, Appendix C), it is evident that the variable is predominantly made up of zeros. Statistical techniques that have the capacity to deal with an excess number of zeros in the distribution were considered and it was decided to analyse Prospective Memory with the zero-inflated negative binomial (ZINB) model which is a specific version of the zero-inflated Poisson (ZIP) model. The ZINB model is a two-part model that separately considers the proportion of a zeros occurring in the distribution and the distribution of non-zero values occurring in the two groups. “Thus, we can base the test on a test of equality of the proportion of zeros and a test of equality of the distribution of non-zeros” (Lachenbruch, 2002, p. 298). The ZINB model is preferred to the *t*-test or Wilcoxon test in samples with excess zeros and can easily be extended to include covariates (Lachenbruch, 2002). Intelligence was used as a covariate. The results of the least square means of the ZINB corrected data are given in Table 10.

Table 10

Least Squares Means for Prospective Memory

	Not Adjusted for IQ		Adjusted for IQ	
	Estimate	*SE*	*Estimate*	*SE*
Prospective memory				
Experimental	2.332	.057	2.281	.059
Control	2.481	.052	2.443	.052

Note
SE = Standard Error.

The least square mean of the experimental group as shown in Table 9 above shows a greater change when it is adjusted for intelligence relative to the control group. In order to compare the groups on Prospective Memory performance with the ZINB model, the least square means are compared. The difference between the least square means are given in Table 11.

Table 11

Differences between Least Squares Means for Prospective Memory

	Estimate	*SE*	*z*	*p*	*95% CI*	
					LL	*UL*
Prospective Memory	-.15	.08	-1.93	.054	-.3	.003
Prospective Memory adjusted for IQ	-.16	.07	-2.17	.030*	.075	1.202

Note. CI = confidence interval; *LL* = lower limit, *UL* = upper limit.
* $p < .05$. ** $p < .01$

As shown in Table 11, after the variable Prospective Memory is adjusted for the effect of IQ, the variable shows a significant difference across the groups. The control group showed a significantly better performance on the task assessing Prospective Memory when compared to the experimental group.

It has been speculated that non-cognitive variables may have a mediating effect on the way that noise could affect children's performance on tests of memory and attention. In previous studies it has been speculated that noise sensitivity, noise annoyance and the children's main language spoken at home could have such a possible mediating effect (Hygge et al., 2002; Stansfeld & Matheson, 2003; Stansfeld et al., 2005). In order to determine whether these non-cognitive variables could have confounding or mediating effects on the results of this study's comparisons, the variables sensitivity to noise, sensitivity to aircraft noise, annoyance at school and at home and main language spoken at home were correlated with each other and the cognitive variables in order to see if any significant correlations arose. The variables were measured using the Child Questionnaire, which is a self-report measure that was given to the participating children to complete. The variables sensitivity to noise and sensitivity to aircraft noise were variables based on numerous questions around noise annoyance and coping mechanisms used to cope with the noise. Both of these variables were dichotomous variables with a "1" indicating non-sensitivity and "2" indicating sensitivity. The variables annoyance at school and annoyance at home were based on different questions on the level of annoyance felt and the variable main language assessed whether the participant spoke English as a first or second language. The Pearson correlations are given in Table 11.

Table 12

Pearson correlation coefficients between cognitive and non-cognitive variables

	Group	Sensitivity	Sensitivity-Aircraft	Annoyance School	Annoyance Home	Main Language	IQ	Information Recall	Recognition Memory	Prospective Memory	Working Memory	Attention
Group	1	-.159**	-.290**	-.416**	-.099**	-.010	-.013	-.060	-.086*	.056	-.076*	-.007
Sensitivity	-.159**	1	.343**	.243**	.174**	.085*	-.117**	-.041	-.032	-.038	.041	-.063
Sensitivity-Aircraft	-.290**	.343**	1	.370**	.217**	.086*	-.096*	-.036	-.039	-.002	.000	-.082*
Annoyance School	-.416**	.243**	.370**	1	.388**	.050	-.128**	-.070	-.046	-.022	-.024	-.022
Annoyance Home	-.099**	.174**	.217**	.388**	1	.053	-.091*	-.026	-.056	.006	-.002	.001
Main Language	-.010	.085*	.086*	.050	.053	1	-.198**	-.267**	-.257**	-.160**	.078	-.098*
IQ	-.013	-.117**	-.096*	-.128**	-.091*	-.198**	1	.512**	.400**	.190**	.064	.362**
Information Recall	-.060	-.041	-.036	-.070	-.026	-.267**	.512**	1	.603**	.232**	.085*	.298**
Recognition Memory	-.086*	-.032	-.039	-.046	-.056	-.257**	.400**	.603**	1	.192**	.106**	.245**
Prospective Memory	.056	-.038	-.002	-.022	.006	-.160**	.190**	.232**	.192**	1	.035	.151**
Working Memory	-.076*	.041	.000	-.024	-.002	.078	.064	.085*	.106**	.035	1	.012
Attention	-.007	-.063	-.082*	-.022	.001	-.098*	.362**	.298**	.245**	.151**	.012	1

* $p < .05$. ** $p < .01$

As can be seen in Table 12, there were no significant correlations among the variables that would warrant investigation of possible mediator variables.

This chapter has presented the statistical analyses utilised to answer the research questions that were posed. The implications of the results that were presented here will be discussed in the next section in relation to the theory and previous research that were presented earlier.

Chapter 4: Discussion

This research aimed to contribute to the existing body of knowledge on the effect of aircraft noise on children's memory and attention. Consequently, assessments were undertaken of the memory and attention of children who were attending schools situated near an airport in Durban, South Africa. The schools were divided into high-noise and low-noise exposed schools. Children's memory and attention were assessed through the use of the Child Memory Scale (Cohen, 1997) for episodic memory, the Search and Memory Task also known as Letter Detective (Smith & Miles, 1987) for working memory, an ad hoc measure of prospective memory where children needed to sign their initials at specific points during the assessment and the Toulouse Pieron Test (Toulouse & Pieron, 1986) for attention. This study was modelled on a European study called the Road Traffic Noise and Children's Cognition and Health (RANCH) study (Stansfeld et al., 2005). This is particularly important since this is the first study of its kind to be conducted on the African continent.

The results from the current study were mixed and in some instances unexpected. They resembled the results from previous studies but there were also some novel findings. Before explanations for the different results are explored, the results will be summarised. Non-verbal intelligence was used as a covariate to control for this possibly confounding factor when significant differences were found among the groups. Firstly, episodic memory was assessed by considering recognition memory and information recall. Performance on the recognition memory test was significantly higher in the noise-exposed group, when compared with the quiet group, even after adjustment for intelligence. Further, chronic aircraft noise was not significantly associated with poor information recall for either group. Secondly, the noise-exposed group showed significantly higher working memory functioning when compared to the quiet group. This was also still significant even after adjustment for intelligence. Thirdly, exposure to chronic aircraft noise was associated with lower scores on the test for prospective memory in the noise-exposed group when the noise-exposed and quiet groups were compared, after an adjustment was made for the impact of intelligence. Lastly, sustained visual attention did not show any significant effect with chronic aircraft noise and this remained non-significant even after adjustment for intelligence.

Episodic memory, as measured by information recall, did not show a significant effect with chronic aircraft noise. This finding corroborates that of several previous studies, where no significant effect was also found (Haines et al., 2001a; Haines et al., 2001b; Matheson et al., 2010; Stansfeld et al., 2005). The Munich Airport study did however find a significant impairment in information recall with chronic aircraft noise (Evans et al., 1995). In the current study, episodic memory as measured by recognition memory did show a significant effect with chronic aircraft noise but it was in favour of the noise-exposed group. Therefore, performance on the test for recognition memory was significantly higher in the noise-exposed group than in the quiet group. This was an unexpected finding as other studies have not found the same result. However, the effect size was very small (d = .172). Some studies found a significant effect on recognition memory with chronic aircraft noise, but in favour of the control group (Haines et al., 2001b; Matheson et al., 2010; Stansfeld et al., 2005). Only one study did not find a significant effect for recognition memory with chronic aircraft noise (Haines et al., 2001a).

In the current study, there was a significant difference between noise-exposed and quiet groups on a test of working memory, favouring the noise-exposed group. This result remained significant at the .01 level after adjustment for intelligence. However, the effect size was very small (d = .230). This result is in contrast to most other findings as working memory has been found to be either not affected at all or impaired by chronic aircraft noise (Evans et al., 1995; Evans et al., 1998; Haines et al., 2001a; Haines et al., 2001b; Hygge et al., 2002; Matheson et al., 2010; Stansfeld et al., 2005).

The findings presented above are difficult to explain as they go somewhat against previous findings. Therefore, previous explanations ventured for effects seen in episodic and working memory when exposed to aircraft noise, such as a masking effect on sub-vocal speech as well as classroom effects such as impairment in intelligibility of teachers' speech, are not applicable in the present study. Some more recent research suggests that prolonged exposure to noise may actually increase working and episodic memory capacity through several mechanisms or nullify its effect (Smith et al., 2010). These include the processes of habituation, as well as stochastic resonance which is "where stimuli presented under a detection threshold can be detected in the presence of noise" (Smith et al., 2010, p. 235). Stochastic resonance has been given as a possible process by which noise can actually improve memory functioning. A significant improvement in memory functioning in the presence of noise has been seen among children that have attention-deficit hyperactivity disorder (ADHD) and this has been found in more than one study (Sikstrom & Soderlund, 2009). The problem in using stochastic resonance as a viable explanation for the results in the current study lies in the complexity of the process. Stochastic resonance only applies in certain circumstances among a certain cohort of participants and in very specific and constant noise levels (Sikstrom & Soderlund, 2009). For this reason, the variability in sound frequency and amplitude seen with aircraft noise, stochastic resonance cannot be put forth as a viable explanation for the results seen. The main way that these results will be explained is to explore the possible effect of noise habituation and how this could explain better working and recognition memory performance under conditions of chronic aircraft noise. Also, since the effect sizes that were found for the difference in working and recognition memory were very small and could indicate little meaningful difference between the groups, habituation will also be regarded as a possible explanation of why there would be no significant effect of chronic aircraft noise on the mentioned memory functioning. Also, it has been hypothesised that noise may only impact memory systems when there is a certain degree of cognitive complexity in the tasks that are used to assess the memory system. The tasks that participants were required to do in this study may not have been complex enough for noise to have a significant effect. Since these two explanations will be ventured to explain the results found in this study, research on noise habituation and the impact of the cognitive complexity of tasks will be discussed below.

Habituation to noise, where noise initially impairs performance on cognitive tasks, with the effect later diminishing even to a point where cognitive performance may be increased, may explain the findings of the current study (Smith et al., 2010). The process of habituation can explain why memory functioning might be unaffected or even improve with exposure to noise. Habituation to sound, the process whereby “prior noise exposure leads to a reduced effect of subsequent exposure”, is an alternative way to view the interaction between noise and memory and are subsumed under the area of investigation called “positive sound exposures” (Smith et al., 2010, p. 235). An experiment was conducted that considered the habituation to noise in an office environment. The experiment required that participants do mental arithmetic while sound effects (both irrelevant office sounds and classical music) were played in the background. In the beginning the participants showed severe impairment in their ability to do this cognitive task, but after about ten minutes the participants were seen to improve on the task. The experimental group even did significantly better than the control group who were tested in a quiet environment. This was then claimed to be indicative of habituation to the noise (Smith et al., 2010). Although this experiment points to habituation in the short term, the authors claim that the same principles might apply to habituation to noise over longer periods of time. However, not all studies investigating habituation to noise found it to be present. Jones, Macken and Mosdell (1997) did an experiment where university students were subjected to irrelevant sound that came out of loudspeakers while they had to perform a recall task. The sound was either repetition of a word, a sentence or quiet. They had to remember a series of letters and type it into a computer after a certain time of being exposed to the sound. The experimental groups performed significantly worse than the quiet group even when the experimental groups had been listening for 20 minutes to the sound. This, they said, rules out the possibility of habituation to sound. The difference between this experiment and reality is, however, that in real life conditions, the time that people are exposed to sound is a great deal longer than 20 minutes. The second thing that has not been considered in the said experiment is that habituation is also a great deal more complex in that it may not only affect memory functioning alone but also sleeping patterns.

Disrupted sleeping patterns due to traffic and aircraft noise during the night-time can have a mediating effect on cognitive functioning of children. Loss of sleep as a mediating factor has been used in some studies to explain reduced performance of children on cognitive tasks such as memory and attention tasks (Stansfeld & Matheson, 2003). Kawada et al. (2000) investigated habituation of sleep to noise. Eleven students slept in a laboratory-type setting and were monitored with a wrist device, self-report questionnaires and a performance test in order to assess their sleep quality. They were there over a period of seventeen days. These students were subjected to road traffic noise at night after five days of quiet. On average, the investigators found that sleep quality, that would initially decrease, again reached the levels seen during quiet nights after only five nights of exposure to noise. This points to habituation of sleep to noise. Therefore, if disrupted sleep is seen as a possible mediator between exposure to noise and impaired memory functioning, then habituation of sleep to this noise might explain why no such impairment in memory functioning is seen.

A second hypothesis for the results is that noise only impairs complex cognitive tasks, with tasks not requiring complex higher order cognition not being affected by noise (Van Kempen et al., 2010). This may then mean that the measures they used in the current study did not sufficiently pick up the effects of exposure to chronic aircraft noise since they were simple and not interfered with by noise.

Hygge (2003) and Van Kempen et al. (2010) found significant differences between noise exposed and non-noise exposed only on items that had a greater degree of cognitive complexity. This suggests that exposure to chronic aircraft noise might only become visible or only affect memory and attention when there is a considerable degree of complexity associated with the task that needs to be completed. A study that used more than one test each to assess working memory and attention found that the more complex and demanding parts of the tests assessing working memory and attention showed significantly greater impairment with noise exposure than the more simple tasks (Van Kempen et al., 2010). Huang and Pashler (2005) investigated the effect that task difficulty has on attention capacity. Using three kinds of search tasks, they attempted to ascertain if with increased task difficulty, there would be limits to attentional capacity. The findings indicated that with an increase in the visual search task difficulty, the efficiency of the search is impaired although it does not affect absolute limits of attention (Huang & Pashler, 2005). This indicates that when tasks are more complex, they could slow down cognitive processing and could thereby negatively affect cognitive performance. This may thus indicate that the findings of the present study may be due to the measures not making heavy demands on memory or attentional capacity and therefore not requiring as much higher order processing from the participants. In the present study, the cognitive complexity of the working memory task, Letter Detective, was investigated by comparing the groups also on the different tasks within Letter Detective. A definite trend of an increase in difficulty was found but significant differences were found only for the middle band tasks. The easiest and the most difficult tasks did not show significant differences. This could indicate that, even though the working memory task increases in difficulty, it does not reach a sufficient level of complexity to see noise impact on the working memory functioning.

One aspect of memory functioning that has been found to be more complex and requiring greater executive functioning capacity, is prospective memory (Smith, 2003). As mentioned in the literature review, prospective memory is one of the most important memory systems in everyday life and also for children in a classroom context. Children are often asked in a classroom context by their teacher to do something after they have finished with a task or at a specific time. Therefore, it was appropriate to also include this variable in assessing the effects of aircraft noise on children’s cognition.

The results showed that chronic aircraft noise was associated with poorer prospective memory, after an adjustment was made for the impact of intelligence. The only other study to have investigated the possible effect of aircraft noise on children's prospective memory was the European RANCH study. No significant effect was found in this study (Matheson et al., 2010; Stansfeld et al., 2005). It must be noted, however, that the specific way that prospective memory was measured and scored differed across the latter and current study. In the European study, prospective memory was assessed on two trials where the participant needed to sign their initials at two predetermined points. It was also scored binomially (i.e. a 1 was given if the participant responded exactly as required and a 0 if the participant made a mistake of any kind). The researchers themselves noted that the variable was relatively weak because there were only two trials (Matheson et al., 2010). In the present study, prospective memory was assessed using three trials, where participants needed to sign their initials at three predetermined points in the battery of tests. Scores were given based on whether the participant signed their initials, wrote their name or made a random mark and if that was put next to the correct item number, any place on that page or at a random place in the test. Therefore, the scoring was more complex than in the European study and allowed for a greater variation in scores, as well as a greater ability to differentiate between participants. This could possibly explain why a significant result was found in the present study and not in the European study.

A possible way for this finding to be interpreted is within the multi-process framework of prospective memory (McDaniel & Einstein, 2000). The attentional processes inherent in prospective memory, where attention needs to be sustained in terms of a task and then to be switched to another task or intention that needs to be realised, form the basis of both main processes inherent in the multi-process framework. This type of memory is very sensitive to changes or impairments in these attentional processes. Where prospective memory performance is poor there may be a disruption in attentional processes that mediate the effect on prospective memory. Thus, the air traffic noise may cause such a disruption in attention. This explanation can only be ventured tentatively as there was no significant effect found on sustained attention and other types of attention were not assessed. However, there are research findings that seem to suggest that noise only affects memory when sufficiently complex tasks are used to assess the memory system, as described earlier (Hygge, 2003; Van Kempen et al., 2010). Since only sustained attention was assessed, it is possible that exposure to chronic aircraft noise could impair the complex transient attentional processes inherent in the monitoring of the environment for or automatic cueing of target cues, thereby leading to impaired prospective memory.

The importance of attentional processes in memory functioning cannot be stressed enough and therefore attention was also included in the analyses. There was no significant difference between the noise-exposed and quiet groups on the test of sustained attention. Previous studies that also investigated the effect of chronic aircraft noise on sustained attention found mixed results. All studies that were considered found no effect of aircraft noise on sustained attention (Evans et al., 1995; Haines et al., 2001b; Stansfeld et al., 2005).

There are many possible explanations for why sustained attention does not seem to be affected at all by chronic aircraft noise. One possible reason for this could be the specific type of attention that was measured in the current study. As mentioned earlier in the literature review, attention can be divided into sustained and transient components (Nakayama & Mackeben, 1989). Smith (1991) indicated that sustained attention was negatively affected in situations where noise levels reached or were higher than 95 dB for a considerable amount of time continuously (up to 30 minutes) and the task did not encourage a sense of caution (as compared to dangerous tasks were a sense of caution is needed). Studies investigating the effect of moderate intensity noise on cognitive vigilance tasks also indicated some interference by the noise on these tasks, but was dependent on the type of task as well as the duration of the noise. It is possible that, since the noise levels in the current study did not exceed 70 dB, this may be there reason why it did not have an effect on sustained attention.

The findings in this study were somewhat unexpected since it has gone somewhat against intuition and previously held hypotheses. Performance on the working and recognition memory tasks were significantly better in the noise exposed group when compared to the non-noise exposed group. However, since the effect sizes for both of these results were very small, it can be said that they have little practical meaning. Habituation to noise as well as the impact of the cognitive complexity of tasks were ventured as possible explanations for these results. Attention and information recall did not show any significant differences across the groups. The non-noise exposed group performed significantly better than the noise exposed group on the task of prospective memory, after adjustment was made for the impact of intelligence. This finding is the first of its kind in such a field study. This was explained by considering that the attentional processes and high cognitive load of prospective memory make it an easier target for noise to interfere with when compared to sustained or focused attention.

Limitations of the Study

There are several limitations to the study that might have affected the findings that were outlined above. These are bound up in the specific nature and characteristics of aircraft noise as opposed to other types of noise. This has far reaching implications for the way that aircraft noise is defined, classed and measured. The specific nature of aircraft noise that makes it unique also makes it extremely difficult to generalise findings of a study to “noise effects” in general and it also makes it extremely difficult to explain the results of such a study based on other “noise effects” studies. Therefore the two major limitations and difficulties of the present study have to do with the way that aircraft noise is characteristically different to other types of noise, as well as the difficulty in comparing the results of experimental studies with naturalistic studies. A further limitation is inherent in the naturalistic setting that the study takes place in. Consequently there are confounding effects of multiple extraneous variables that could not be controlled for.

In terms of how aircraft noise differs from other types of noise, it is necessary to consider how one should view differences in sound. For the purposes of this study the focus was on duration, in particular the distinction between acute and chronic noise. Aircraft noise is classed as chronic noise. However, “chronic noise” as defined in a laboratory setting differs to aircraft noise. Firstly, chronic noise in a laboratory setting would be more or less continuous (hence making it “chronic”). This is not the case with aircraft noise. Aircraft noise is not completely continuous, as airplanes would pass by in a naturalistic setting every now and then, not continuously. Secondly, chronic noise in a laboratory setting would be more or less the same amplitude throughout an experiment. This is also not true of aircraft noise in a naturalistic setting, as the amplitude of the noise as an airplane passes overhead differs according to its position on its flight path relative to the ground (or place where the measurement is taken). This limitation would therefore not be unique to this study, but would be inherent in most of the naturalistic studies investigating the effects of aircraft noise. Even when considering the comparison of road traffic noise, railroad traffic noise and aircraft noise, these “chronic” noise sources also differ in their frequency and amplitude. Therefore it goes beyond the difficulty of comparing “chronic” noise in laboratory settings with naturalistic settings, even in naturalistic settings making these noise sources equivalent would be problematic.

Another limitation to the present study is the specific way that noise is seen to impact children's cognition. This again is an instance where studies making use of laboratory settings and naturalistic settings cannot realistically be compared. In experimental studies noise is used as a once-off exposure, after which the effects of the noise are studied, whereas naturalistic studies make use of prolonged exposure to noise. Thus the extent of exposure to noise would influence the explanations and theories used to describe how noise affects memory. The present study however, being naturalistic, examined the impact of noise on children in their everyday environment. It would therefore not be applicable to use the same theories and explanations as to why noise would affect (or not affect) memory in experimental studies. The "noise" that is used in a naturalistic setting would then be expected to affect children in the longer term and not necessarily just in the moment as they are taking a memory test. In a laboratory setting noise would interact directly with memory while a memory test is being taken but in a naturalistic setting, as in the present study, it would be assumed that exposure to the noise had already interacted on the development of the brain and memory systems over a period of time. This makes it important to conduct longitudinal studies. Therefore results indicating that noise impacts on memory (or not) could not necessarily be equal when found in a laboratory setting or in a naturalistic setting since more complex processes (such as the formation of coping strategies) are involved in naturalistic settings.

This limitation is illustrated in a study conducted to compare the effects of aircraft noise and irrelevant speech on prose memory (Sorqvist, 2010). In this study, the experiments to assess the impact of aircraft noise on children's prose memory involved the researchers playing simulated aircraft noise through speakers to the children in a classroom setting. Even though the simulation was true to life (it even accounted for the sound coming through a brick wall), the effect of aircraft noise was tested in an immediate and once-off way. The results of such a study could not realistically be compared to results of naturalistic studies that have been conducted where exposure is prolonged (Evans et al., 1995; Evans et al., 1998; Haines et al., 2001a; Haines et al., 2001b; Hygge et al., 2002; Stansfeld et al., 2005). Since naturalistic studies actually focus on the effects of noise on the development memory systems and laboratory studies focus on the immediate effect of noise on memory systems, they may also require quite different explanatory frameworks since different phenomena are being studied.

The third limitation to the study is the possible confounding effect that numerous extraneous variables may have on the results of the study. First of all, it is almost impossible to study the long-term effects of aircraft noise on children's cognition in isolation. Invariably, other sources of sound will also be present and can easily augment or nullify the effect that aircraft noise may have, for example noise near their place of residence. Secondly, it is extremely difficult to create equivalence among participants and groups in naturalistic studies even when controlling for intelligence. Even though many variables were considered and many characteristics were taken into account when the experimental and control groups were matched, such as socioeconomic status, total equivalence cannot be assumed. It is therefore possible that many variables, aside from those studied and controlled for, could have influenced the outcome of this study.

Contribution to Knowledge

Despite these limitations in the study, the contributions to knowledge in the field of aircraft noise and cognition made by the current study are valuable. Since it is part of the larger study, RANCH-SA, and therefore modelled on the European RANCH study, results from this study can be easily compared to the European RANCH study (Stansfeld et al., 2005). The results from this study can also be compared to other studies such as the Munich airport study and the West-London schools study since parts of the methodology overlap (Evans et al., 1995; Evans et al., 1998; Haines et al., 2001a; Hygge et al., 2002). The present study, and the larger project of which it forms part, is also the first of its kind on the continent and therefore contributes to the knowledge in this field cross-culturally. Also, the inclusion of prospective memory as a dependent variable and the innovative analysis technique added greatly to the current knowledge on chronic aircraft noise and prospective memory.

The findings of better working and recognition memory performance within the experimental group, thereby suggesting possible increases in working memory and recognition memory with increased aircraft noise provide some assistance to previous studies that found similar results but ascribed the findings to methodological errors. Apart from contributing to existing knowledge in the form of unexpected findings as well as the significant finding of prospective memory, the findings of the study also point to some ways to further refine and improve on the existing methods of conducting this type of research.

Directions for Future Research

For future research in the area of aircraft noise and cognition there are several recommendations that can be made based on the findings of the present study as well as the limitations outlined above.

In terms of the investigation of different memory systems, more than one measure on each variable as well as measures with increased complexity could prove to uncover significant effects of exposure to chronic aircraft noise on memory systems, if this effect does in fact exist. It is also important to do longitudinal research to see how noise affects memory and attention over time.

The aspects of attention that were studied in the present study and other studies in the field may not be sufficient. Including measures of other aspects of attention such as the transient processes of attention may be fruitful and could possibly provide greater explanatory power when trying to assess whether or not aircraft noise do actually have an effect of attention as it is used in different aspects of working memory and prospective memory. The Toulouse Pieron Test could in future studies be augmented by the Switching Attention Test (SAT) and Simple Reaction Time Test (SRTT) to obtain a clearer picture of possible effects of aircraft noise on different aspects of attention (Van Kempen et al., 2010).

Conclusion

The effect of noise pollution is considered by some to be a modern day plague with noise associated with many health risks in both adults and children (Falzone, 1999; Goines & Hagler, 2007). Noise, and more specifically road traffic and aircraft noise, have been associated with health risks ranging from sleep disturbance, hypertension, cardiovascular disease and annoyance (Stansfeld & Matheson, 2003). The effects of aircraft noise on the cognition of children have also been studied but with mixed results and findings (Matheson et al., 2010; Stansfeld et al., 2005; Stansfeld & Matheson, 2007). Although impairment in reading comprehension with exposure to chronic aircraft noise was found in past research, effects on different memory systems and attention have been mixed and disparate (Evans et al., 1995; Evans et al., 1998; Haines et al., 2001a; Haines et al., 2001b; Hygge et al., 2002; Stansfeld et al., 2005).

The results of this study were novel in that significant differences for working and recognition memory were seen, favouring the noise exposed group, even though the effect sizes were very small. The finding that performance on prospective memory was significantly better in the non-noise exposed group was also a novel finding and might prove very useful for future studies. Hypotheses of why non-significant results were found for attention and information recall as well as the small effect sizes seen for working and recognition memory, centered around the process of habituation to noise as well as the impact of the cognitive complexity of the tasks used to measure the different variables.

The current study aimed to contribute to the knowledge in this field by investigating the effects of chronic aircraft noise on a sample of school children in terms of their episodic memory, working memory, prospective memory and also attention. Results were mixed but made definite contributions to knowledge in the field. The limitations inherent in this study as well as limitations in previous similar naturalistic studies were considered and recommendations for future research in the area were offered.

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APPENDIX A: Ethical Approval Document

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

HUMAN RESEARCH ETHICS COMMITTEE (SCHOOL OF HUMAN & COMMUNITY DEVELOPMENT

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: MACC/11/002 IH**
PROJECT TITLE:	The Effects of Aircraft Noise on Children's Memory and Attention.
INVESTIGATORS **DEPARTMENT**	Louw Phillipus Psychology
DATE CONSIDERED	23/03/11
DECISION OF COMMITTEE*	Approved

This ethical clearance is valid for 2 years and may be renewed upon application

DATE: 19 May 2011

CHAIRPERSON ________
(Professor M. Lucas)

cc Supervisor: Prof Kate Cockcroft
Psychology

DECLARATION OF INVESTIGATOR (S)

To be completed in duplicate and **one copy** returned to the Secretary, Room 100015, 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 be contemplated from the research procedure, as approved, I/we undertake to submit a revised protocol to the Committee.

This ethical clearance will expire on 31 December 2013

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX B: Consent Letters

KWA-ZULU NATAL DEPARTMENT OF EDUCATION

UMTHOMBO WOPHUHLISO LOLUNTU
School of Human & Community Development

Psychology
School of Human & Community Development
University of the Witwatersrand
Private Bag 3, WITS, 2050
Tel: (011) 717 4500 Fax: (011) 717 4559

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

INFORMATION LETTER

Dear Madam/ Sir

My name is Joseph Seabi, and I am conducting research for the purpose of obtaining a PhD degree at the University of the Witwatersrand. The focus of this research is on investigating the effects of exposure to aircraft noise on learners' reading comprehension, attention and working memory. The proposed study aims to compare performance of learners exposed to chronic aircraft noise and those from relatively quiet areas on reading comprehension, attention and working memory, before-and-after decommissioning of the airport. The practical implications of this study impact on the location of schools and sound proofing of schools. This study will also inform researchers and policy makers of the potential of subgroups of learners who are at higher risk for negative effects of noise, as well as the effects thereof. A thorough understanding of the non-auditory effects of noise on cognition will facilitate the formulation of strategies and counter-measures to reduce noise levels.

It should take the learners approximately two hours to complete the questionnaires. Participation of learners in this research include filling out questionnaire asking information such as their age, gender, health, school work, and how they deal with noise at home and school. In addition, they will be required to complete four tasks (i.e. reading comprehension, immediate and long-term memory, working memory and attention). Participation of teachers include responding to a questionnaire, which covers aspects such as years taught at the school, their health, perception of noise and learners' behaviour in the classroom.

Participation is voluntary, and no person will be disadvantaged in any way for choosing to participate or to withdraw at any time. Confidentiality will be ensured, and only my supervisor and I will have access to the data. No identifying information will be included in the research report. On completion of my research report the data will be destroyed. Both teachers and learners will also be asked to complete a form showing that they are willing to participate in the study.

Should you allow the study to take place, would you be so kind as to sign the consent letter granting me permission.

Should you have any questions please do not hesitate to contact me on the number below during working hours. You may also contact my supervisors, Prof. Kate Cockcroft on (011) 717-4511 or e-mail her at kate.cockcroft@wits.ac.za; and Dr. Paul Goldschagg on (011) 717-3172 or email him at paul.goldschagg@wits.ac.za.

Thank you for your kindness.

Mr. Joseph Seabi

(011) 717-8331; E-mail: joseph.seabi@wits.ac.za

CONSENT LETTER

I --, the representative of Kwa-Zulu Natal Department of Education, do hereby grant Joseph Seabi permission to conduct his research in our district.

(Please Print)--------------------------------------- at -------------------------- on--------------

Signature-----------------------------------

School of Human & Community Development

Psychology
School of Human & Community Development
University of the Witwatersrand
Private Bag 3, WITS, 2050
Tel: (011) 717 4500 Fax: (011) 717 4559

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

PRINCIPAL INFORMATION LETTER

Dear Sir/Madam

My name is Joseph Seabi, and I am conducting research for the purpose of obtaining a PhD degree at the University of the Witwatersrand. The focus of this research is on investigating the effects of exposure to aircraft noise on learners' reading comprehension, attention and working memory. The proposed study aims to compare performance of learners exposed to chronic aircraft noise and those from relatively quiet areas on reading comprehension, attention and working memory, before-and-after decommissioning of the airport. Further comparisons will be made between low and high noise sensitive learners exposed to aircraft noise on such cognitive tasks. The practical implications of this study impact on the location of schools and sound proofing of schools. This study will also inform researchers and policy makers of the potential of subgroups of learners who are at higher risk for negative effects of noise, as well as the effects thereof. A thorough understanding of the non-auditory effects of noise on cognition will facilitate the formulation of strategies and counter-measures to reduce noise levels.

I therefore wish to request your permission to conduct my research in your school. It should take the learners approximately two hours to complete the questionnaires. I understand that this is a substantial investment of time. However their response is valuable as it will contribute towards a South African understanding of whether chronic exposure to aircraft noise impact on reading comprehension, attention and working memory.

Participation of learners in this research include filling out questionnaire asking information such as their age, gender, health, school work, and how they deal with noise at home and school. In addition, they will be required to complete four tasks (i.e. reading comprehension, immediate and long-term memory, working memory and attention). Participation of teachers include responding to a questionnaire, which covers aspects such as years taught at the school, their health, perception of noise and learners' behaviour in the classroom.

Participation is voluntary, and no person will be disadvantaged in any way for choosing to participate or to withdraw at any time. Confidentiality will be ensured, and only my supervisor and I will have access to the data. No identifying information will be included in the research report. On completion of my research report the data will be destroyed. Both teachers and learners will also be asked to complete a form showing that they are willing to participate in the study.

Should you allow the study to take place in your school, would you be so kind as to sign the consent letter granting me permission.

Should you have any questions please do not hesitate to contact me on the number below during working hours. You may also contact my supervisors, Prof. Kate Cockcroft on (011) 717-4511 or e-mail her at kate.cockcroft@wits.ac.za; and Dr. Paul Goldschagg on (011) 717-3172 or email him at paul.goldschagg@wits.ac.za.

Thank you for your kindness.

Mr. Joseph Seabi

(011) 717-8331; E-mail: joseph.seabi@wits.ac.za

PRINCIPAL CONSENT LETTER

I --, the principal of ……………………………., do hereby grant Joseph Seabi permission to conduct his research in my school.

(Please Print)-------------------------------------- at -------------------------- on--------------

Signature-----------------------------------

UMTHOMBO WOPHUHLISO LOLUNTU
School of Human & Community Development

Psychology
School of Human & Community Development
University of the Witwatersrand
Private Bag 3, WITS, 2050
Tel: (011) 717 4500 Fax: (011) 717 4559

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

PARENT INFORMATION LETTER

Dear Parent/Caregiver

My name is Joseph Seabi, and I am conducting research for the purpose of obtaining a PhD degree at the University of the Witwatersrand. The focus of this research is on investigating the effects of exposure to aircraft noise on learners' reading comprehension, attention and working memory. The practical implications of this study impact on the location of schools and sound proofing of schools. A thorough understanding of the non-auditory effects of noise on cognition will facilitate the formulation of strategies and counter-measures to reduce noise levels.

I wish to invite you to grant permission for you and your child to participate in the study. The entire process should not take more than two hours for learners to complete the tasks, and will be conducted with the permission of the school in a time that will be specified by the school.

Participation of learners in this research include filling out a questionnaire asking information such as their age, gender, health, school work, and how they deal with noise at home and school. In addition, they will be required to complete four tasks (i.e. reading comprehension, immediate and long-term memory, working memory and attention). Participation of parents include filling out a questionnaire which covers aspects related to your child's health, sleeping patterns, and perception of noise at home. It should take you less than thirty minutes to respond to the questionnaire.

Participation in this study is voluntary. Should you choose not to provide your consent your child will not be disadvantaged. He/she will thus not participate in the research and you will not have to respond to this letter. Should you grant consent, I ask you to please complete and return the form below. In addition, your child has the right to choose not to participate or to withdraw from the study at any time.

Once more, I assure you that all responses are confidential. All questionnaires will be destroyed after I have analyzed them. Should you have any questions please do not hesitate to contact me on the number below during working hours. You may also contact my supervisors, Prof. Kate Cockcroft on (011) 717-4511 or e-mail her at kate.cockcroft@wits.ac.za; and Dr. Paul Goldschagg on (011) 717-3172 or email him at paul.goldschagg@wits.ac.za.

Thank you for your kindness.

Mr. Joseph Seabi

(011) 717-8331; E-mail: joseph.seabi@wits.ac.za

PARENT CONSENT FORM

I --- parent of ------------------------------ in Grade ----- have read and understood the information provided in this consent form. I grant permission for my child to participate in the study conducted by Joseph Seabi.

I understand that:

- Participation in this study is voluntary
- I may withdraw my child from the study at any time without our child suffering any prejudice
- No information that may identify my child or his/her family will be included in the research report, and his/her responses will remain confidential.

(Please Print)--------------------------------------- at -------------------------- on--------------

Signature-----------------------------------

UMTHOMBO WOPHUHLISO LOLUNTU
School of Human & Community Development

Psychology
School of Human & Community Development
University of the Witwatersrand
Private Bag 3, WITS, 2050
Tel: (011) 717 4500 Fax: (011) 717 4559

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

TEACHER INFORMATION LETTER

Dear Sir/Madam

My name is Joseph Seabi, and I am conducting research for the purpose of obtaining a PhD degree at the University of the Witwatersrand. The focus of this research is on investigating the effects of exposure to aircraft noise on learners' reading comprehension, attention and working memory. It should take the learners approximately two hours to complete the questionnaires. I understand that this is a substantial investment of your time. However your response is valuable as it will contribute towards a South African understanding of whether chronic exposure to aircraft noise impact on reading comprehension, attention and working memory.

Participation of in this research include responding to a questionnaire, which covers aspects such as years taught at the school, your health, perception of noise and learners' behaviour in the classroom.

Participation is voluntary, and no person will be disadvantaged in any way for choosing to participate or to withdraw at any time. Confidentiality will be ensured, and only my supervisor and I will have access to the data. No identifying information will be included in the research report. On completion of my research report the data will be destroyed.

Should you be willing to participate in the study, would you be so kind as to sign the consent letter granting me permission.

Should you have any questions please do not hesitate to contact me on the number below during working hours. You may also contact my supervisors, Prof. Kate Cockcroft on (011) 717-4511 or e-mail her at kate.cockcroft@wits.ac.za; and Dr. Paul Goldschagg on (011) 717-3172 or email him at paul.goldschagg@wits.ac.za.

Thank you for your kindness.

Mr. Joseph Seabi

(011) 717-8331; E-mail: joseph.seabi@wits.ac.za

TEACHER CONSENT LETTER

I --, the teacher of ……………………………., do hereby consent to participate in a study conducted by Joseph Seabi. I understand the following conditions:

- My participation in the study is completely voluntary.
- I will not in any way be disadvantaged by agreeing to fill out the questionnaires.
- The questionnaires are confidential.
- My responses may be used but no information that could identify me will be included in the researcher's report.
- I have the right to withdraw from the study at any stage.
- I may refuse to answer any questions in the questionnaire which I would rather not answer.

--- -------------

Signature Date

(Please Print)--------------------------------------- at -------------------------- on--------------

Signature-----------------------------------

School of Human &
Community Development

Psychology
School of Human & Community Development
University of the Witwatersrand
Private Bag 3, WITS, 2050
Tel: (011) 717 4500 Fax: (011) 717 4559

LEARNER INFORMATION SHEET

Dear Learner

My name is Joseph Seabi, and I am conducting research for the purpose of obtaining a PhD degree at the University of the Witwatersrand. This study is looking at whether learners exposed to aircraft noise experience difficulties with reading comprehension, attention and working memory. Should you choose to participate in the study, you will be required to answer questions with a pencil. The entire process should not take more than two hours. Participation in this research will include filling out questionnaire asking information such as your age, gender, health, school work, and how you deal with noise at home and school. In addition, you will be required to complete four tasks (i.e. reading comprehension, immediate and long-term memory, working memory and attention).

Participation in this study is voluntary, and you will not be disadvantaged in any way for not choosing to participate in the study. You may refuse to answer any questions you would prefer not to, and may choose to withdraw from the study at any point.

If you desire any further information, please do not hesitate to contact me telephonically on (011) 717-8331 during working hours or via e-mail at joseph.seabi@wits.ac.za. You may also contact my supervisors, Prof. Kate Cockcroft on (011) 717-4511 or e-mail her at kate.cockcroft@wits.ac.za; and Dr. Paul Goldschagg on (011) 717-3172 or email him at paul.goldschagg@wits.ac.za.

Thank you for your kindness.

Mr. Joseph Seabi

LEARNER ASSENT FORM

I --, in Grade------- assent to participate in the study conducted by Joseph Seabi. I understand the following conditions:

- My participation in the study is completely voluntary.
- I will not in any way be disadvantaged by agreeing to fill out the questionnaires.
- The questionnaires are confidential.
- My responses may be used but no information that could identify me will be included in the researcher's report.
- I have the right to withdraw from the study at any stage.
- I may refuse to answer any questions in the questionnaire which I would rather not answer.

--- -------------

Signature Date

APPENDIX C: Histograms

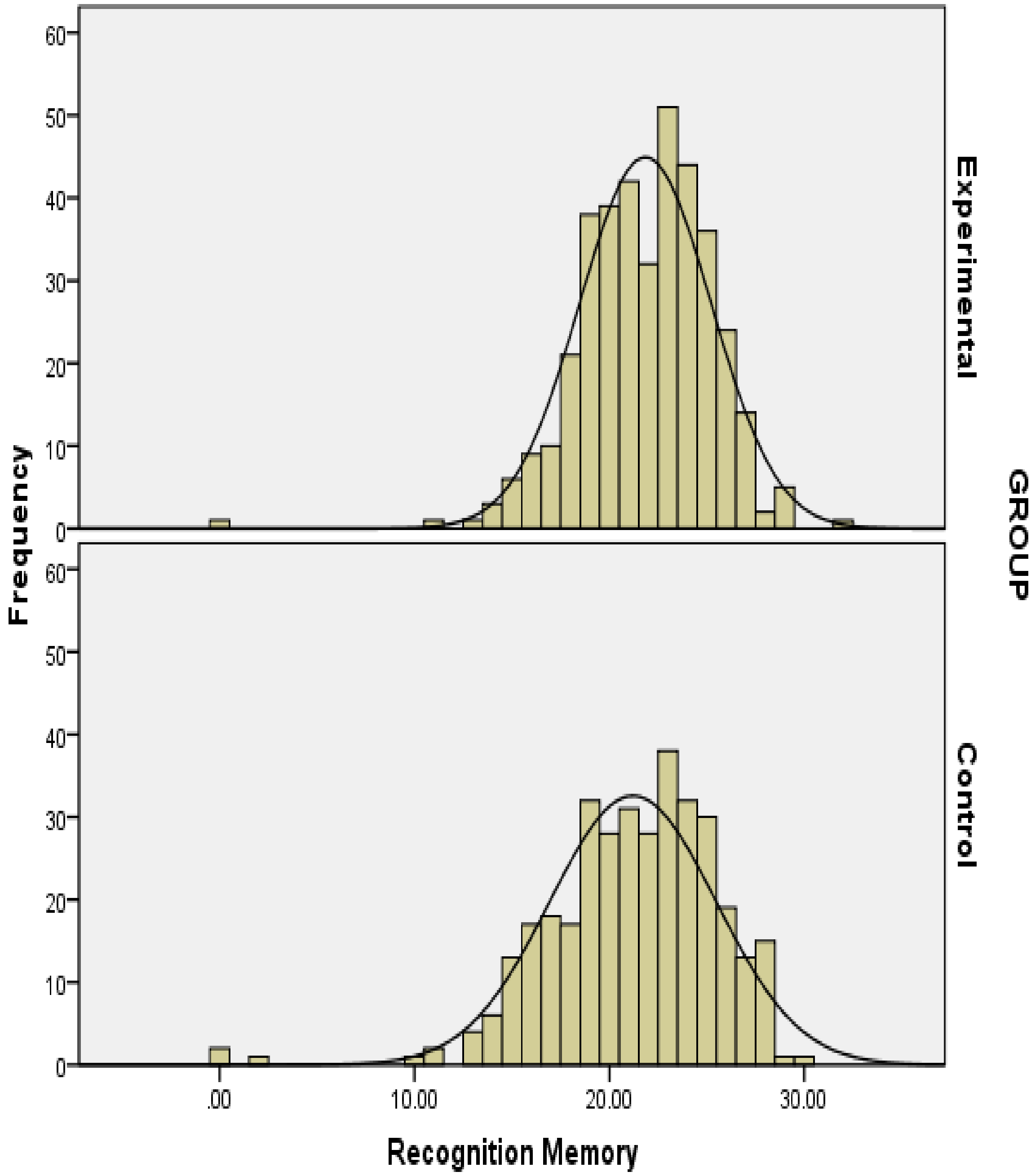

Figure 1. A histogram of each of the two groups' scores on Recognition Memory

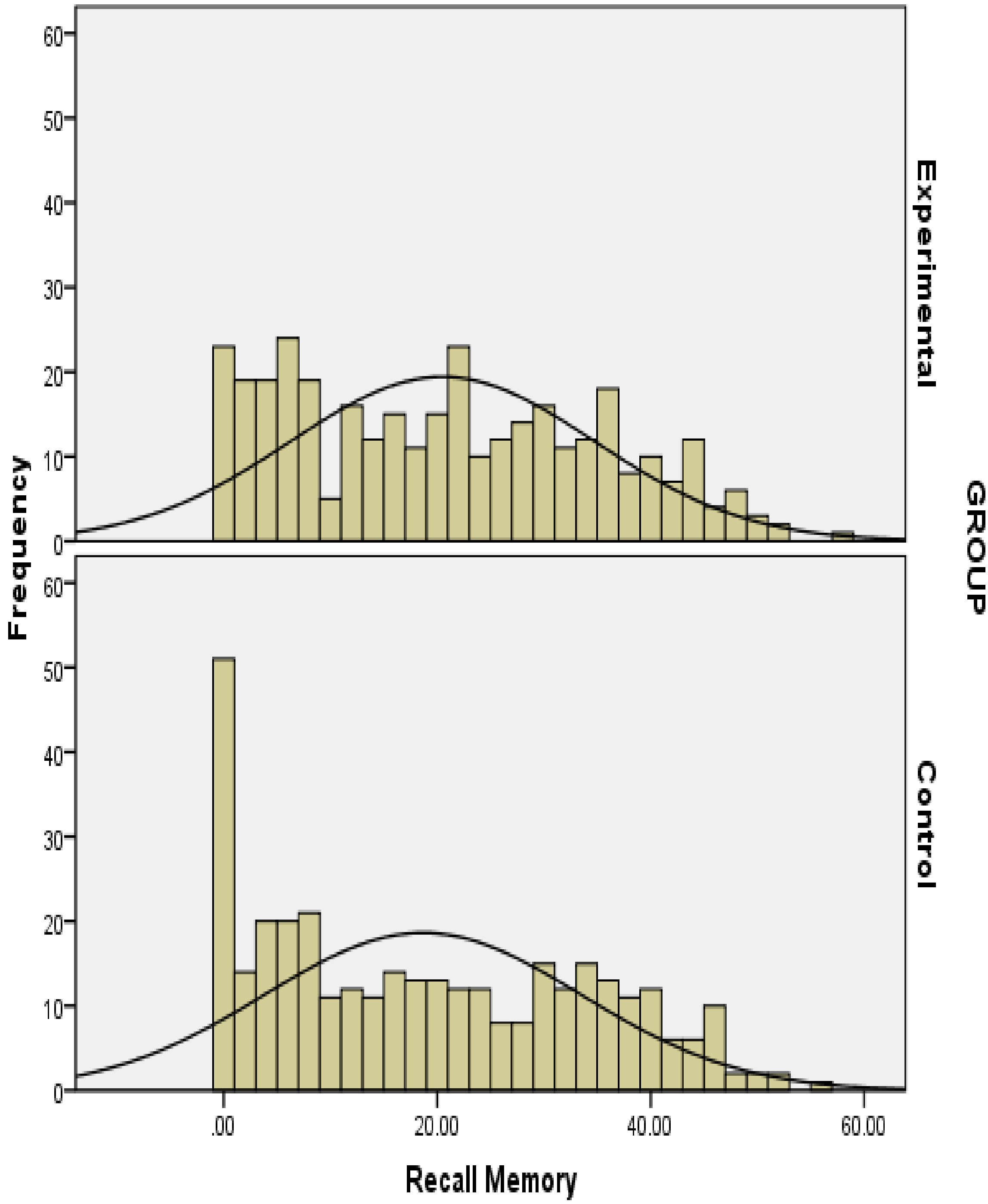

Figure 2. A histogram of each of the two groups' scores on Recall Memory

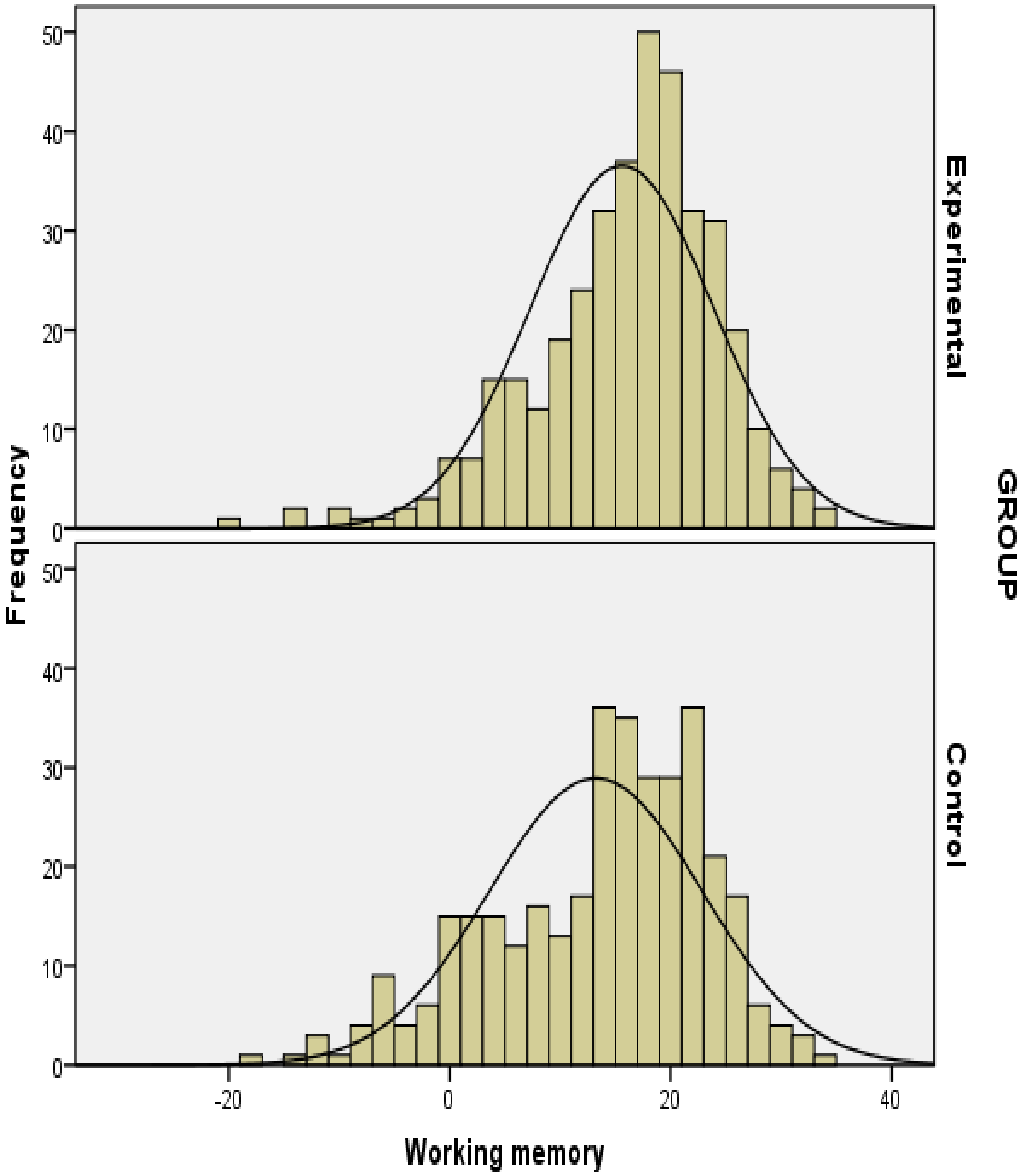

Figure 3. A histogram of each of the two groups' scores on Working Memory

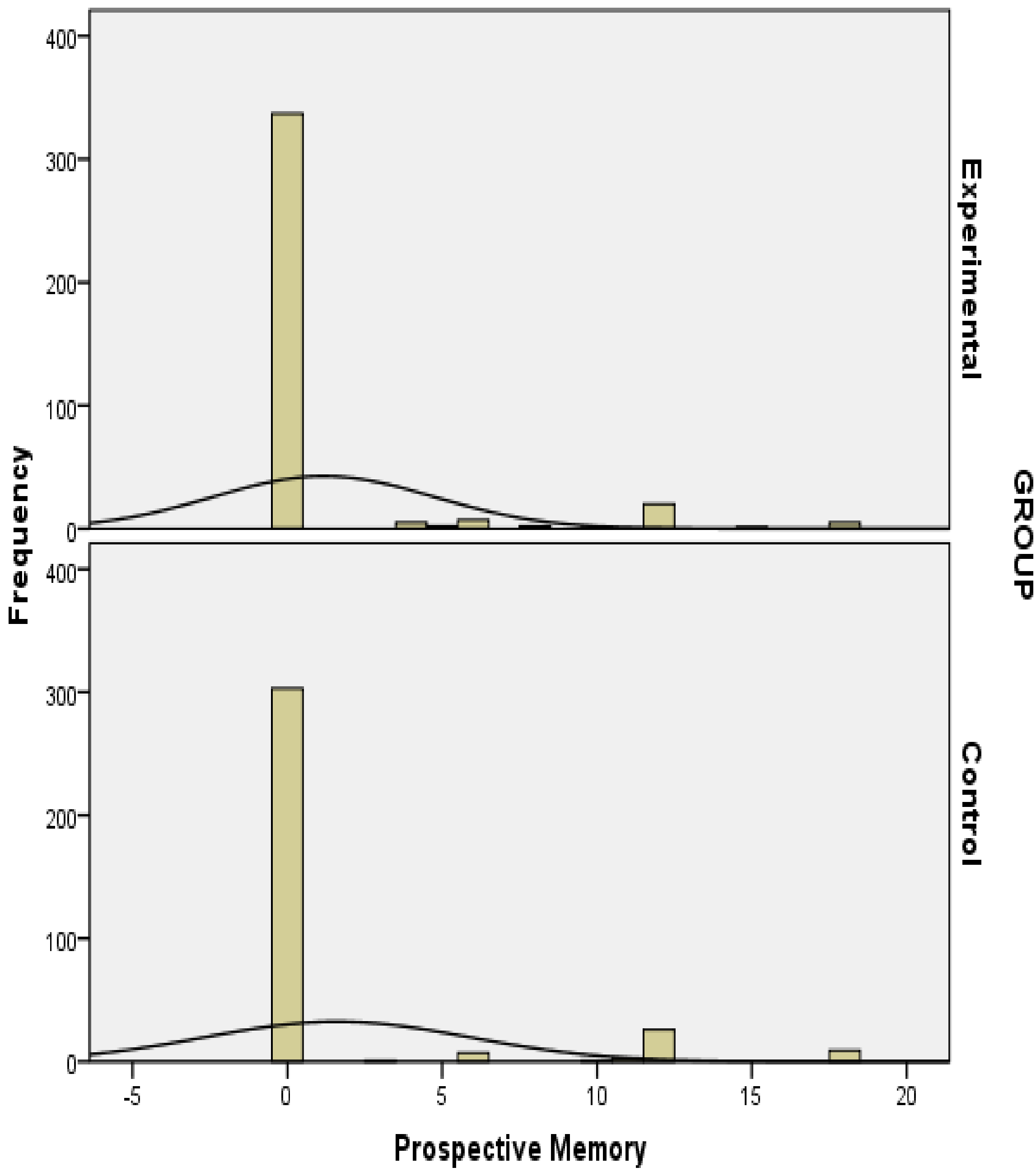

Figure 4. A histogram of each of the two groups' scores on Prospective Memory

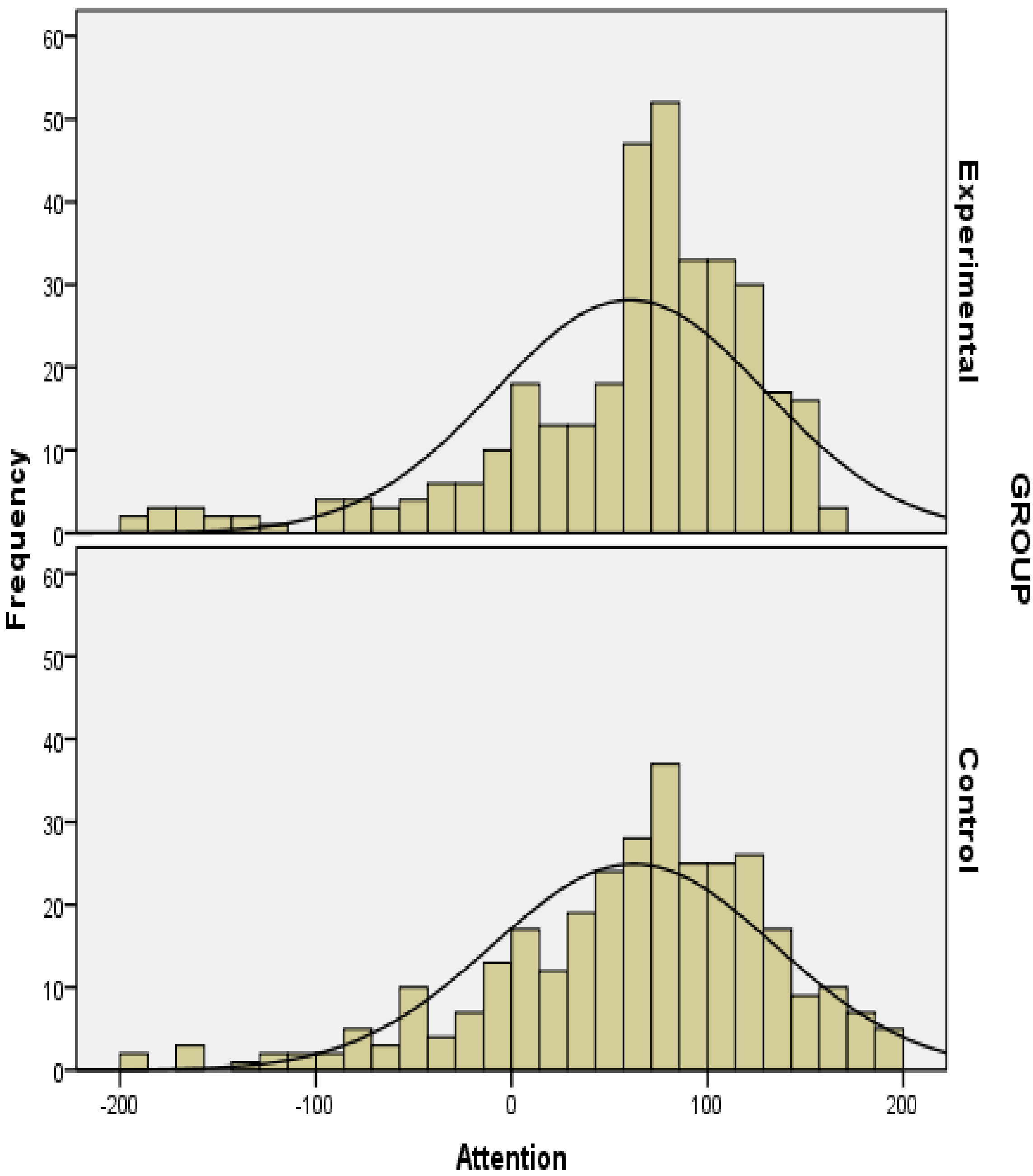

Figure 5. A histogram of each of the two groups' scores on Attention