CHAPTER 1: INTRODUCTION

The role of air traffic control (ATC) is to manage aircraft within the airspace and on the ground in order to ensure safety and efficiency at all times (Wickens, Mavor & McGee, 1997). The complex nature of ATC requires controllers to utilise a number of cognitive functions which enable them to identify and respond to numerous sources of information within their environment (Bellorini, Larsen, Pistre, Considine, Woldring & Van Dame, 1999; Eurocontrol, 1996; Wickens et al., 1997). Although the importance of such functions in controller performance has been established in previous research, visual analysis has not been considered.

Visual analysis has been identified as a vital skill and predictor of performance in a number of occupations namely: closed circuit television (CCTV) surveillance; X-ray screening in aviation; and radiology (Andrew, Landgrebe & Donald, 2003; Department for Transport, 2003; Donald, 1998a; Donald, F. 2011). However, visual analysis has not been researched within the context of ATC. This research set out to determine the relevance of visual analysis to ATC, in particular whether there is a relationship between visual analysis and performance during training on the Core Content course attended by aspiring controllers. Identifying visual analysis as a specific ability contributing to controller performance during training, serves as an opportunity to enhance success rates of training, but also to ensure effective performance as qualified controllers.

1.1. Rationale

Visual analysis has been identified as being an important ability required in a number of occupations such as: closed circuit television (CCTV) surveillance operators; X-ray screeners in aviation; and radiologists (Andrew, Landgrebe & Donald, 2003; Department for Transport; Donald, 1998a; Donald F, 2011). The ability to successfully operate within these occupations demands intensive visual analysis skills.

Within ATC, controllers perform multiple tasks relying on information from a number of different sources (Durso & Manning, 2008; Wickens et al., 1997). While some of the information is auditory (e.g. radiotelephony), other information is visual (e.g. radar, weather displays, and visual scans of runways) (Ellis, 2006; Metzger & Parasuraman, 2006). A number of cognitive functions have been identified as crucial of the ability for controllers to handle these various inputs (Bellorini, 1999; Durso & Manning, 2008; Eurocontrol, 1996). The Information Processing Model by Wickens et al. (1997), highlights the importance of specific cognitive functions in determining the ability for controllers to respond accordingly. However, when examining the visual component of ATC, the relevance of visual analysis should be considered.

Certain errors within ATC have been attributed to controllers failing to perceive critical information presented on displays or to recognise and understand the given situation, and thus being unable to respond appropriately (Stein, 1989; Wickens et al., 1997). In response to this, when examining controller performance; the ability of visual analysis should be considered in addition to the cognitive functions identified in the research.

Realising the crucial role of ATC in ensuring the safety of aircraft, determining the relevance of visual analysis to controller performance serves as a major advancement in understanding how this may be achieved.

1.2. Focus of the research

The focus of this research is to examine whether there is a relationship between visual analysis and performance during the first training course attended by aspiring controllers. Visual analysis was assessed using ScreenX and SAMAE's Scanning and Division of Attention exercises from Leaderware cc. The performance of trainees was based on Core Content course reports provided by the Air Navigation Service Provider (ANSP).

1.3. Structure of the research

The following section of Chapter 2 provides a theoretical and conceptual background to the study. The role of ATC and the cognitive functions required to perform ATC tasks are identified. The ATC training process is then outlined and the importance of cognitive ability in trainee performance is acknowledged. Thereafter, the concept of visual analysis is introduced and its relevance to ATC is explained. The chapter ends with a statement of the research hypotheses. The methodology for this study is presented in Chapter 3 which describes the research design, sample, procedures, instruments and analysis used. The results and summary of results are provided in Chapter 4. In Chapter 5 a discussion based on the results of the current study is presented which is followed by contextualising these with respect to prior research. Thereafter, the limitations of this study and recommendations for future research are discussed. And lastly, the conclusion of this study is presented in Chapter 6.

1.4. Acronyms used

A list of the acronyms used in the current research is presented in Table 1.

Table 1 List of Acronyms

Acronym	Meaning
ATC	Air Traffic Control
ATM	Air Traffic Management
ANSP	Air Navigation Service Provider
FPS	Flight Progress Strips
ICAO	International Civil Aviation Organisation
TRACON	Terminal Radar Approach Control

CHAPTER 2: THEORETICAL BACKGROUND

This chapter provides a theoretical background to the current study. The literature review begins with describing the role of Air Traffic Control (ATC) and cognitive functions involved in performing ATC tasks, as well as specific cognitive stages presented by Wickens et al.'s Information Processing Model (1997). This is followed by outlining the ATC training process and role of cognitive ability in training performance. Visual analysis forms part of the last section of the literature review where a description and understanding of the concept is presented. Thereafter, visual analysis is applied to the context of ATC and an explanation for why it should be considered in the current study is provided.

2.1. The Role of Air Traffic Control (ATC)

The role of ATC is to manage aircraft within the airspace and on the ground in order to ensure '... the safe, efficient flow of traffic from origin to destination' (Wickens et al., 1997, p.21). According to the International Civil Aviation Organization (ICAO), ATC is a service which is '... provided for the purpose of preventing collisions between aircraft, and on the manoeuvring area between aircraft and obstructions [as well as] expediting and maintaining an orderly flow of air traffic' (International Civil Aviation Organization Annex 11, p.3).

The first priority of ATC is to guarantee aircraft safety. In this respect, the organised flow of air traffic and ensuring minimum separation between aircraft (in order to prevent future collision) is of central importance. Separation which must be maintained throughout the flight path is defined by altitude and lateral dimensions determined by different regions within the airspace (Durso & Manning, 2008). Whilst ensuring that the safety of aircraft is maintained, ATC is also expected to ensure that aircraft are managed in the most efficient way possible. Efficiency is achieved by issuing fuel-efficient routes, as well as by adhering to arrival and departure schedules stipulated by airways management. Advances in technology have further improved the efficiency of ATC allowing the sequencing of aircraft hours in advance. Such advances have enabled ATC to reduce the amount of fuel and overall cost to airlines. The task of ATC is therefore a challenging one; as it requires the most efficient management of aircraft without compromising safety (Wickens et al., 1997).

ATC performs three important functions: ‘Pre-flight briefing, assistance and advisory services to pilots during flight; providing control and separation of en route air traffic; and control and separation of air traffic at airports’ (U.S. Office of Personnel Management, 1978, p.4). These functions are divided across three air traffic facilities which are tasked with controlling aircraft within specific areas and heights and require constant communication and coordination. The ICAO refers to these facilities as: aerodrome control, approach control and area control (ICAO Annex 11). Other terms used in the literature to refer to these as tower, TRACON (terminal radar approach control facilities) and en route centers (Durso & Manning, 2008). For the purposes of this paper the terms; tower, area and radar control will be used (Wickens et al., 1997).

Tower control consists of ground controllers who manage ground traffic - such as aircraft ground movements (moving aircraft to and from the gate via the taxiway to the runway) and vehicles; and local controllers who manage take-offs and landings (Wickens et al., 1997).Tower controllers are responsible for issuing clearance (i.e. speed, altitude and heading) to aircraft, based on confirming prior schedules and flight plans as provided by airline dispatchers for take-offs and landings (Durso & Manning, 2008). By utilising radar surveillance, tower controllers are able issue clear instructions to pilots detailing the speed, altitude and heading/direction in which the aircraft should travel. Tower control is further responsible for handing over departing aircraft to departure control, or to accept arriving aircraft from approach control stationed at the radar facility (Wickens et al., 1997).

Within the radar facility, radar controllers are responsible for managing air traffic being handed over from either tower or area control. Radar controllers may be stationed at departure control, which manages the handing over of departing aircraft from tower control to area control. They may also be located at approach control, managing arriving aircraft from area control to tower control (Wickens et al., 1997). The task of radar control is to ensure aircraft are sequenced effectively so as to maintain safe separation between aircraft. Throughout this process, radar controllers are not only required to monitor lateral movement of, but also the rate of descending or climbing of such aircraft within the airspace. Radar controllers are responsible for managing aircraft within a designated sector of the airspace where, depending on the degree of traffic, radar controllers may be assigned to manage both approach and departure control (Wickens et al., 1997).

Area control (en route control) manages aircraft travelling across country according to specific path-ways at differing flight levels in the airspace (Wickens et al., 1997). Area controllers are designated a sector to manage within the airspace, with each sector consisting of horizontal and vertical boundaries. Area controllers may be designated to manage a sector on their own or in the case of high traffic conditions, two controllers may be designated. In this case, one is tasked with monitoring of radar display and required separation between aircraft, and the other ensuring efficient coordination and handling of flight data (Durso & Manning, 2008).

The ability to manage the airspace evidently rests on the coordination of all three sectors. Each sector is highly dependent on the other as aircraft are continuously handed over from one facility to the next (Durso & Manning, 2008; Wickens et al., 1997). The degree of coordination required and phases of ATC can be seen in Figure 1. The remainder of this paper generally refers to operators within all three of the abovementioned facilities as controllers.

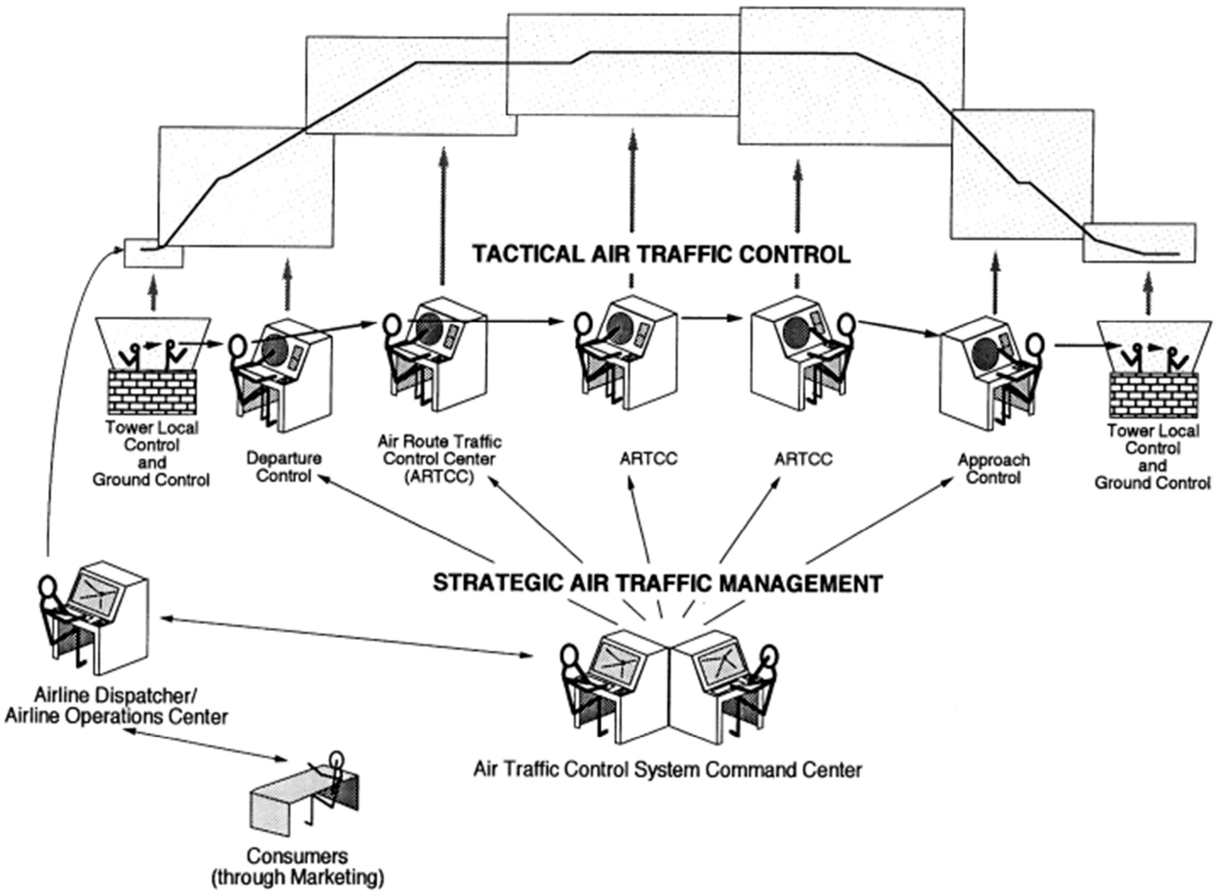

Figure 1. The phases in ATC operations. Billings (1996, as cited in Wickens et al., 1997, p. 20)

The duty of ATC is facilitated by a number of information sources. These are dependent on the type of control facility in which controllers are stationed and, to a large extent, the technology available. Tower controllers (both local and ground controllers) greatly depend on visual sightings of traffic on runways (Figure 2). Tower controllers are further assisted by radar displays (referred to as DBRITE: digital brite, radar indicator tower equipment) which provides a radar presentation of traffic around the airport (approximately 15 miles), as well as aircraft information regarding the identity, type and status of aircraft. Airport surface detection equipment (ASDE) which has only been adopted in some large scale airports, and is in the process of being fully implemented in South Africa (verbal communication with ANSP, 2014), provides radar identification of ground traffic (Wickens et al., 1997).

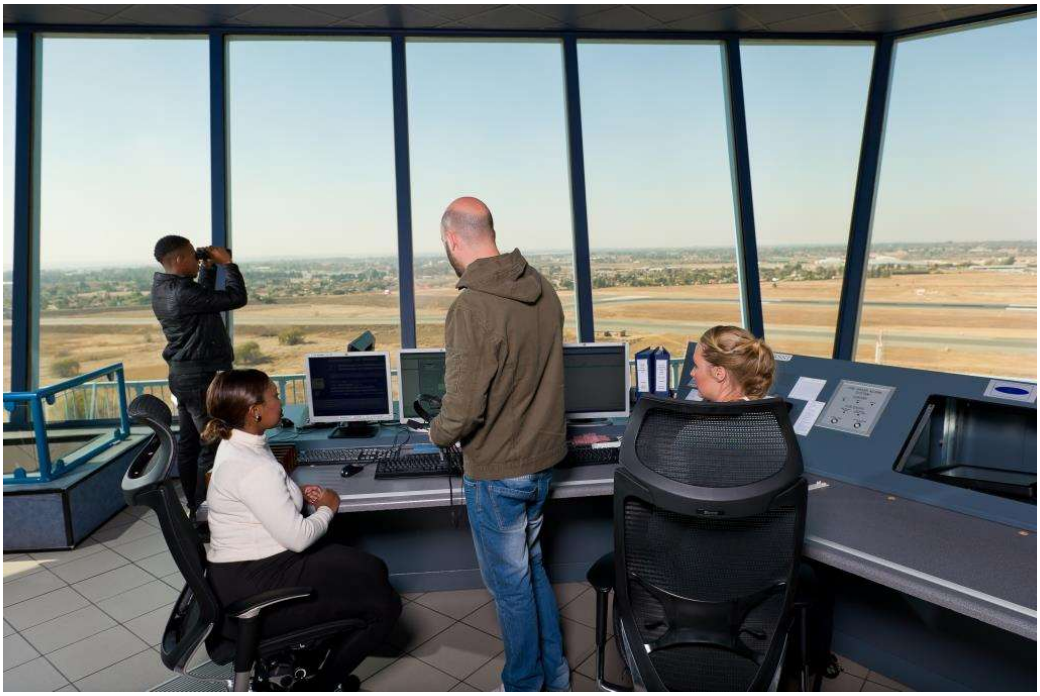

Figure 2. Image of tower control work-station taken from ANSP

Radar and area controllers rely on computer-based, semi-automated radar displays. Radar displays enable controllers to observe current and future positions, predicted path and location of aircraft within the airspace (Durso & Manning, 2008). Each work station receives information via the computer system through primary radar (providing the location of aircraft) and secondary radar (providing the identity of aircraft and altitude of those aircraft equipped with a mode C transponder). Aircraft are represented on the radar display by a block/tag in which the identity and type of aircraft are presented, as well as aircraft status (Wickens et al., 1997) An example of the radar and area controller work-station and radar display is presented in Figure 3 and 4 below.

Figure 3. Image of radar/area work-station taken from ANSP.

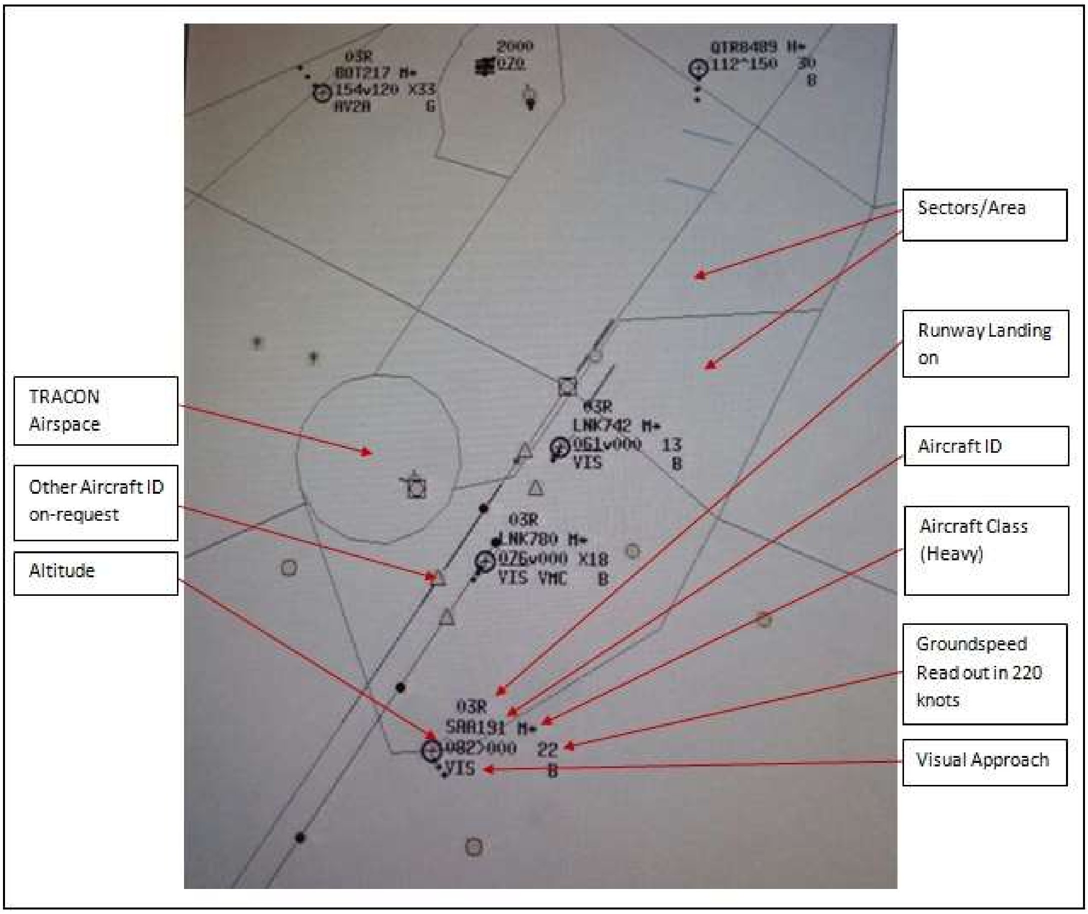

Figure 4. Adapted image of radar display taken from ANSP.

Controllers also receive vital information via automated monitoring systems (Wickens et al., 1997). Not only do these systems provide flight-path predictors, but also provide minimum altitude warnings, as well as conflict alerts for projected and current loss of separation (i.e.an infringement of both horizontal and vertical separation minima within the controlled airspace). (International Civil Aviation Organization, Annex 11, 2001; Wickens et al., 1997).

Beyond utilising radar display and additional systems, controllers also make use of flight progress strips (FPS) detailing the status of aircraft. FPS provide a physical representation of each aircraft and are positioned on the Flight Progress Board (FPSB) representing the position of aircraft within the sector of the airspace being managed by the controller (Figure 5). FPS also serve as a reminder of important information pertaining to specific aircraft and are manually updated by controllers based on the instructions issued to particular aircraft (Figure 6) (Durso & Manning, 2008). Depending on the facility and number of controllers at a given workstation, FPS may also be passed on between controllers with updated information concerning particular aircraft.

Figure 5. Image of Flight Progress Strip Board taken from ANSP.

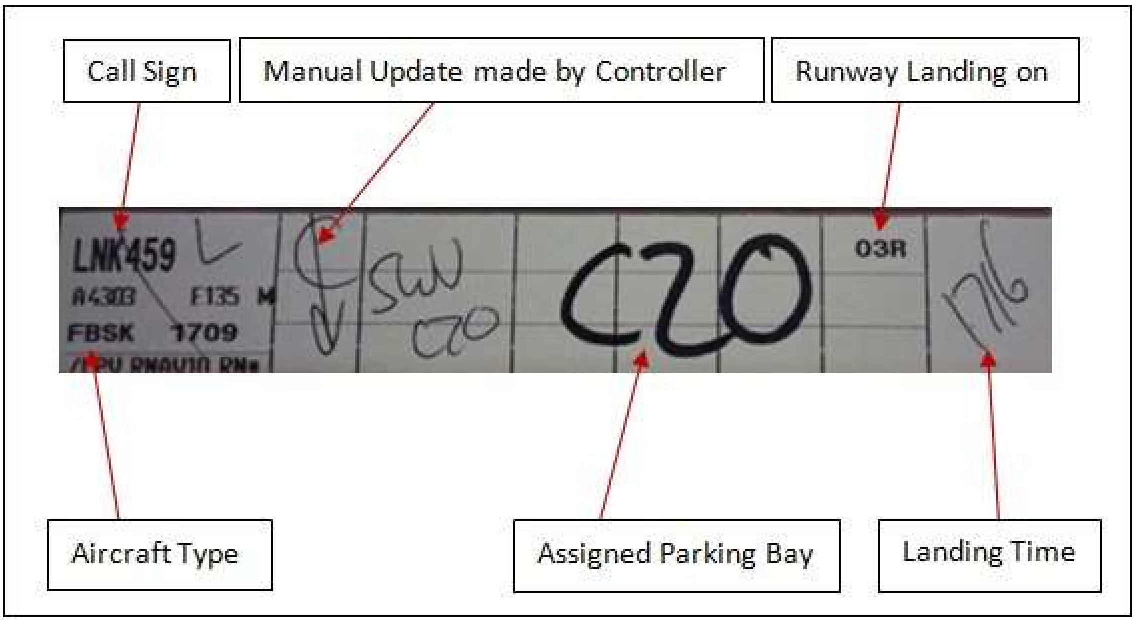

Figure 6. Adapted Image of Flight Progress Strip taken from ANSP.

Communication also functions as an important source of information for controllers. Controllers rely on voice communication in order to communicate with and to identify aircraft on the ground or in the air. Communication with pilots is especially important when issuing clearance for take-off and landing. Controllers also rely on information communicated between one another across the different control facilities. Controllers are required to communicate with one another during the hand-off between each facility. This is especially important for coordination purposes where, for instance, a local controller is able to communicate to radar control whether or not they accept a landing aircraft depending on whether the runway is available (Wickens et al., 1997). Radar control relies on such communication in order to coordinate adjacent sectors when aircraft cross the sector boundaries. With technological advancements, controllers have further been able to coordinate via automatic hand-off, in which the receiving controller receives a message (by the system) allowing them to accept the hand-off, depending on the degree of traffic within the specific sector (Wickens et al., 1997).

The effective management of the airspace requires controllers to interact with, respond to, and make decisions based on various sources of information. Controllers are faced with numerous displays coupled with the dynamic nature of constantly changing images, radiotelephonic interactions with pilots and other operators, FPS and system alerts (International Civil Aviation Organization, 2005). In addition to this, the ability to successfully manage traffic requires controllers to take various contextual complexities into account. For instance: controllers are required to monitor changing weather conditions informed by weather displays; to take into account differing aircraft performance characteristics; the volume of air traffic placed on the system; malfunctions; delays, and other complexities. Being aware of such factors is crucial to anticipate potential conflict and take timely precautions (Durso & Manning, 2008).

2.2. Cognitive Functions

When considering the role of ATC, it is evident that it is a very dynamic, but also an extremely cognitively demanding task (Durso & Manning, 2008). According to Moon, Yoo and Choi (2011) controllers are expected to perform multiple cognitive tasks, most of which take place simultaneously. A number of cognitive factors have been identified namely: perception, attention, memory, information processing and decision making (Bellorini et al., 1999; Durso & Manning, 2008; Eurocontrol, 1996). Other factors which have been identified include mental models and situation awareness (Durso & Manning, 2008; Endsley & Rodgers, 2002). These cognitive factors will be outlined below.

2.2.1. Perception

Perception refers to the process in which information from the environment is received (Wickens & Hollands, 2000). This process involves the use of the five human senses namely: feeling; hearing; sight; smell; and taste. The information received from the environment takes the form of auditory, visual or sensual (Sinanovic & Johnson, 2007). Within the context of ATC, most of the information that controllers are presented with is visual and some of it is auditory (Durso & Manning, 2008; van Meeuwen, 2015). Within their environment controllers are confronted with stimuli from various sources such as radiotelephony, radar displays and other visual displays. The ability to perceive both auditory and visual information from these sources is of vital importance to controllers' ability to effectively manage the airspace (Durso & Manning, 2008).

2.2.2. Attention

Attention is defined as '... sustained concentration on a specific stimulus, sensation, idea, thought or activity enabling one to use information processing systems with limited capacity to handle vast amounts of information available from the sense organs and memory stores' (Colman, 2006). Thus many mental operations are not carried out automatically, but require the selective application of these limited resources (Wickens & Hollands, 2000). Attention has been identified as a crucial factor in determining the ability for controllers to detect and resolve potential problems within their environment (Bellorini, 1999). Four types of attention have been recognised namely: selective attention, divided attention, focused attention and sustained attention (Wickens & Hollands, 2000).

Selective attention

Selective attention is important when individuals must identify appropriate aspects of the environment to process (Wickens & Hollands, 2000). Selective attention is especially important within the context of ATC as controllers are required to pay attention to specific stimuli within the environment in order to gain crucial information. Controllers are expected to know what, where and when to listen to or observe incoming information (Wickens & Hollands, 2000; Wickens et al., 1997). For example, in order to obtain visual information, controllers will direct their vision to different channels in the environment such as: the runway, radar display, FPS or weather displays in order to direct aircraft accordingly.

Divided attention

Divided attention occurs when attention is distributed between two or more stimuli which need to be processed (Wickens & Hollands, 2000). Divided attention is important within a demanding environment such as ATC where controllers are often expected to perform several tasks simultaneously such as: monitoring traffic on the runway or radar display; communicating with pilots; and updating FPS (Durso & Manning, 2008). Divided attention may be affected where the attention demanded to perform these tasks is excessive. Thus, controllers must be able to allocate their attention without limiting their cognitive resources so that they are able to respond to crucial stimuli (Wickens & Hollands, 2000).

Focused attention

Focused attention refers to the ability to concentrate on one source of information whilst ignoring others in the environment (Wickens & Hollands, 2008). The ability to maintain focus is inherently difficult for human beings however, it is especially challenging within the context of ATC given that controllers are faced with numerous sources of information at any given time. For instance, whilst focusing their attention on accepting new aircraft, controllers are presented with extraneous conversations, read-backs from pilots, as well as changing information on both radar and other visual displays. The ability to maintain focused attention may be especially difficult for controllers when considering that divided attention is mandatory for controllers in order for them to perform the range of simultaneous tasks with which they are faced (Wickens & Hollands, 2000).

Sustained attention

Sustained attention refers to the ability of individuals to sustain attention and remain alert to stimuli over long periods of time (Parasuraman, de Visser, Clarke, McGarry, Hussey, Shaw & Thompson, 2009; Warm, Parasuraman & Matthews, 2008). Sustained attention is often used interchangeably with the concept of vigilance, where vigilance has been defined as a form of attention which is '...focused on a source in order to detect a critical but infrequent event' (Donald 2001, p. 36). Vigilance has been recognised as an important cognitive function within the context of ATC as controllers are required to remain vigilant in order to detect unpredictable, but critical events, such as loss of separation, altitude deviations, and incorrect pilot read-backs (Warm et al., 2008; Wickens et al., 1997).

In response to the more recent definitions of vigilance where it is referred to as a process of sustained attention; Donald, F. (2011) warns that the complexity of significant events and the cognitive processes required in vigilance should not be overlooked. The definition proposed by Donald (2001, p. 36) in fact highlights these cognitive processes where vigilance is referred to as '... a capacity for sustained effective attention when monitoring a situation or display for critical signals, conditions or events to which the observer must respond'. Donald (2001) refers to specific cognitive processes such as the ability to identify, recognise and interpret the information presented. According to Donald, F. (2011), the definition provided by Donald (2001) may in fact be better suited to contexts such as ATC in that it recognises that some occupations may require operators to remain vigilant to both frequent, as well as infrequent events.

Donald (2001) further states that vigilance extends beyond sensory recognition and the detection of discrete and simple events, to recognising 'conditions that consist of patterns of events or deviations from norms that may not be immediately apparent' (Donald, 2001, p. 36). This degree of cognitive complexity identified by Donald (2008) aligns with Wickens et al.'s (1997, p. 125) proposal to expand the concept of vigilance '... beyond detection to discrimination, recognition, or diagnosis' of usual conditions'. According to Wickens et al. (1997), such an approach is especially necessary within the context of ATC where, beyond missing a target or failing to respond in time, events are not always understood by controllers in order for them to respond appropriately.

It should, however, be noted that even though such tasks require sustained attention over long periods of time, performance may change over time and detection may become better or worse (Bergum & Lehr, 1963). The vigilance decrement is typically demonstrated by a decline in detection rates and slower detection, which is often demonstrated by an increase in response time over the duration of the task (Wickens et al., 1997). The vigilance decrement is said to occur most commonly within thirty minutes of a watch, although it has been identified within fifteen minutes and under visually demanding conditions, it may occur within five minutes of a watch (Parasuraman et al., 2009; Warm et al., 2008). A number of factors have been associated with the vigilance decrement. Workload and stress have been the most prominent factors identified as taxing the cognitive resources required to perform vigilance intensive tasks (Warm et al., 2008). Certain task related features have also been associated with a decrease in vigilance performance; when information is received at unpredictable times, at a fast rate; when tasks are successive rather than simultaneous; as well as the nature of the target where a low probability of occurrence and temporal uncertainty are said to increase the vigilance decrement (Davies & Parasuraman, 1982; Warm & Dember, 1998; Wickens et al., 1997). Many of these factors are in fact characteristic of ATC. For instance, workload has been identified as one of the key characteristics of controller tasks and often increases the amount of strain placed on controller vigilance (Wickens et al., 1997). Controller workload is often observed by a number of factors such as: air traffic density; complexity of sector routes; quality of displays; controller-pilot communications; and other interactions required. Task related factors are also evident where controllers are constantly faced with targets that are both temporal and spatially unpredictable (Wickens et al., 1997).

2.2.3. Memory

Memory refers to 'a system for storing and retrieving information that is acquired through the five senses' (Bellorini et al., 1999). Memory is a cognitive function that is fundamental to controllers' tasks (Shorrock, 2005). Working memory is a temporary store of information from the environment and is referred to as '... a kind of "workbench" of consciousness where we examine, evaluate, transform and compare different mental representations' (Wickens & Hollands, 2000, p. 241). Depending on the nature of information, it may be temporarily stored within verbal or spatial working memory (Shorrock, 2005). Controllers rely on both verbal and spatial working memory in order to recall aircraft information such as location, flight level, and route, as well as other information pertaining to their environment (Shorrock, 2005). Bellorini et al. (1999) highlights that the limited capacity of working memory presents a challenge to controllers as they are constantly being presented with new information from their environment which must be attended to, in order to do so controllers must to be able to clear information which they no longer need for the current situation.

Long-term memory contains information that is stored over long periods of time and its full capacity is unknown (Wickens & Hollands, 2000). Long-term memory is especially useful as it contains important knowledge structures which assist individuals in the comprehension of situations (Wickens & Hollands, 2000). Knowledge stored in long-term memory is a result of learning or training and is presented in many forms. For instance, some knowledge may be procedural (how to do things learnt from previous experience) and other declarative (knowledge of facts and events). Declarative memory performs an important function of 'chunking' which refers to binding information from various sources in the environment in order to provide a coherent understanding of the given situation. Long-term memory further consists of general knowledge of the world which is presented in episodic memory (memory of specific events and their sequence of occurrence) and semantic memory (knowledge or meaning of words) (Wickens & Hollands, 2000). In the context of ATC, controller knowledge is based on both procedural and declarative memory developed during training such as: ATC procedures; equipment used; aircraft capabilities; and characteristics of the airspace (Bellorini et al., 1999).

Both memory systems (long-term memory and working memory) may be presented as a three-stage process of encoding, storage and retrieval (Wickens & Hollands, 2000).

Encoding is referred to as '... the process of putting things into a memory system' (Wickens & Hollands, 2000, p.241). Information may be encoded into working memory or further transferred from working memory into long-term memory. Information is transferred to long-term memory in the case of learning or training. Storage refers to how information is represented in both working (e.g. visual and auditory) and long-term memory (e.g. procedural and declarative). Retrieval is the last stage which refers to the process of accessing information within these two memory systems (Wickens & Hollands, 2000).

2.2.4. Decision Making

Decision making is typically based on having perceived and evaluated numerous information sources in order to respond in the most appropriate way (Wickens & Hollands, 2000). However, decision making is determined by a number of factors such as: the degree of uncertainty of the consequences of decisions; familiarity and expertise regarding the circumstances in which decisions need to be made; and the time available in which to make decisions (Wickens & Hollands, 2000). Controllers are expected to make accurate decisions within a dynamic environment consisting of a number of actors (e.g. pilots and other controllers), under severe time constraints and often based on a high level of uncertainty or incomplete information (Wickens et al., 1997). Accurate decision making is crucial in the context of ATC given that they ultimately determine the degree to which safety and efficiency may be accomplished.

2.2.5. Mental Models

Mental models may be understood as '... organised knowledge frameworks that allow individuals to describe, explain and predict behaviour' (Lim & Klein, 2006, p. 404). Within complex environments such as ATC, controllers are required to have accurate mental models of the systems used and to continually update their comprehension of the situations they face in real time (Eurocontrol, 1996). Mental models can be established as 'static' knowledge of long-term memory, which is knowledge about how systems work, and the relevant procedures that need to be followed (Wickens, 2002). Within ATC, controllers are continuously taking in information contained in radar displays, weather displays, FPS, and communications. Controllers rely on this information in order to form a mental representation of the airspace, as well as predictions of aircraft movement (Mogford, 1997). Controllers further rely on domain models, which refer to an understanding of the underlying system, its physical design and how it should perform. Controllers may use a variety of domain models such as: the spatial organisation of the airspace; the layout of the airport; and functioning capabilities of a particular aircraft (Mogford, 1997).

Mental models are also present within the team framework - shared mental models refer to how members of a team organise their knowledge of team tasks, equipment, roles and goals in a similar fashion (Lim & Klein, 2006). Shared mental models are critical in complex environments such as ATC where controllers are required to coordinate their actions with each other under severe time constraints within and between different facilities. Mental models (based on pre-existing knowledge) enable controllers to predict one another's actions in order to respond and coordinate actions accordingly. Shared mental models also extend to the relation between controllers and pilots in order to coordinate and anticipate actions.

The formation of mental models is the grounding of knowledge and, in fact, facilitates the ability of operators to form accurate and complete situation awareness (Endsley, 1997; Mogford, 1997). Mental models are important within ATC given that controllers are faced with multiple competing cues. Thus, the way in which attention is employed is essential to determining which aspects of the situation will be processed to form accurate situation awareness. The development of mental models assists in directing the limited attention of controllers in a way in which awareness of, and cues in the environment can be matched to existing models - thereby providing instant situation classification and comprehension (Endsley, 1995).

2.2.6. Situation Awareness

Situation awareness may be defined as '... the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future' (Endsley, 2000, p. 3). Situation awareness has been identified as a crucial component to ATC given that controllers are required to be constantly aware of the parameters (e.g. speed, heading) and current, as well as future projected locations of aircraft (Endsley & Rodgers, 1998). The continued monitoring of aircraft provides controllers with an awareness of the given situation, thus allowing them to maintain the appropriate distance between aircraft, as well as to maintain the flow of traffic (Chiappe,Vu & Strybel, 2012).

There are three different levels of situation awareness namely; perception, comprehension and prediction (Endsley, 1995). At the lowest level, operators are required to perceive relevant information of the system and environment. The second level involves the comprehension of initial perception and the integration of this information in conjunction with task goals. Lastly, level three which is based on the understanding gained at level two, enables operators to make a prediction of future events and system states (Endsley, 1995). In addition to all three levels of situation awareness, the performance of controllers is also greatly determined by three different types of situation awareness: spatial, system and task awareness (Wickens, 2002). Spatial awareness is crucial as controllers must constantly be aware of where aircraft are within the three-dimensional airspace. System awareness becomes important where, for instance, controllers are required to perform certain procedures in emergency situations. Task awareness is crucial where controllers need to be aware of tasks that must be performed (e.g. scanning the runway or radar display, accepting handoffs, and communicating with relevant parties) (Wickens, 2002).

According to Wickens & Hollands (2000), situation awareness constitutes the primary basis for subsequent decision making; whereas Shorrock and Isaac (2010) provide that situation awareness together with mental models, determine the level of understanding of the situation, as well as inform the actions that should be taken by operators.

2.2.7. Information processing

Many of the abovementioned cognitive functions have been analysed from an information processing approach which has been a popular approach to examining these functions - particularly within the context of ATC (Mogford, Murphy & Guttman, 1993; Pawlak, Brinton, Crouch & Lancaster, 1996; Wickens et al., 1997). Broadly stated, information processing assumes that human beings receive and process information from the environment, and respond accordingly (Wickens & Hollands, 2000). The information processing approach has been favoured as it '... allows human cognition to be deconstructed in a way that permits the underlying processes (e.g. decision making, memory) to be studied individually' (Eurocontrol, 1996, p.11). The information processing model by Wickens et al. (1997) has been chosen for the current research due to the fact that it highlights the cognitive functions specific to ATC, namely: selective attention; perception; situation awareness;

planning and decision making; and action execution. In addition, this model is applicable to all three facilities discussed namely; tower, radar and area control (Wickens et al., 1997).

The information processing model by Wickens et al. (1997) is presented in Figure 7 below. According to the model, the task of controllers can be understood by observing how events specific to the context of ATC, presented on the left of the model, drive the actions of controllers, presented on the right of the model. Controller performance is determined by the abovementioned cognitive functions or stages, which are said to intervene between these events and actions (Wickens et al. 1997).

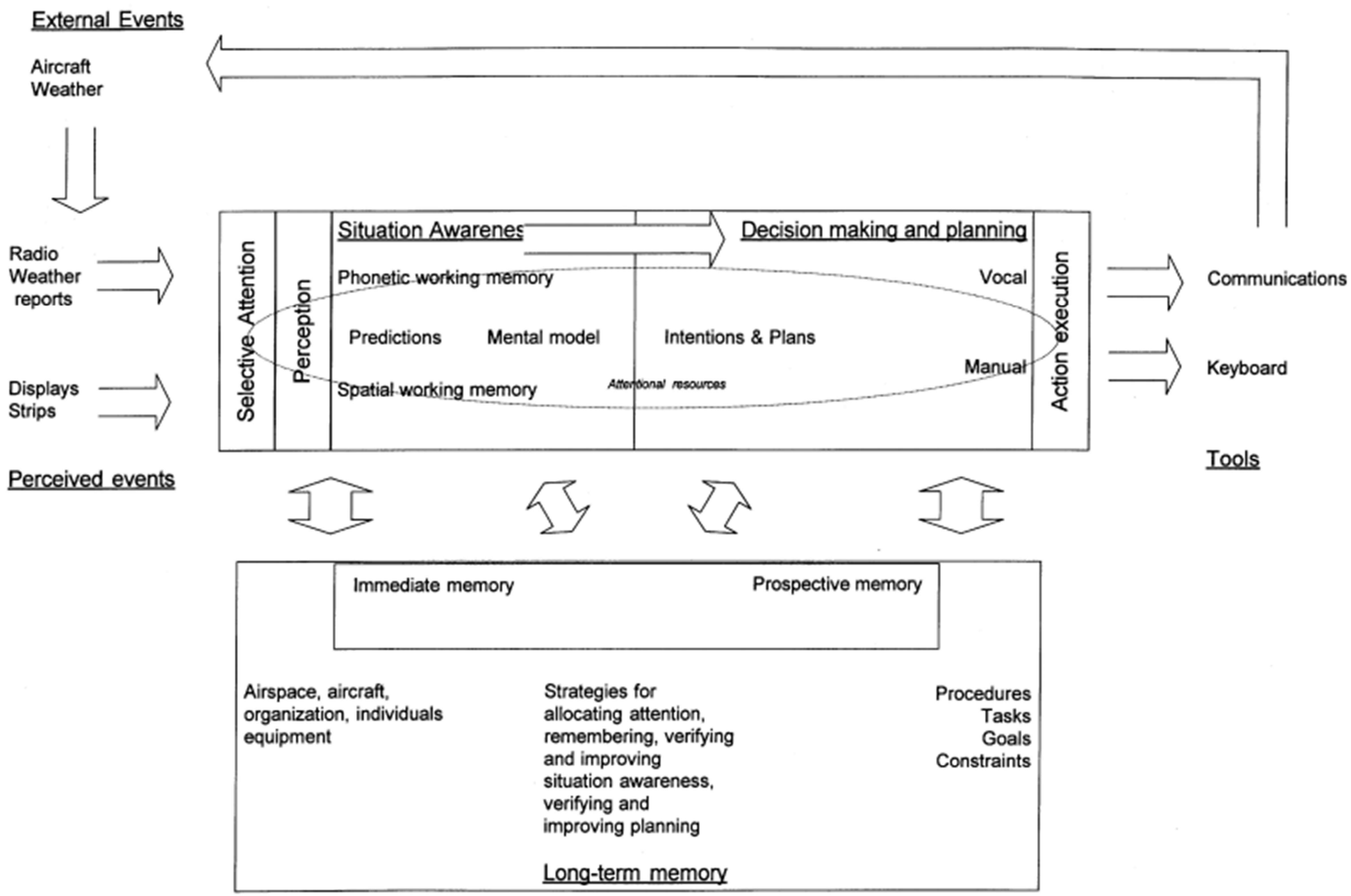

Figure 7. Cognitive model of the controller's task (Wickens et al., 1997, p.93)

According to Wickens et al. (1997), the performance of controllers is to a large degree based on procedures learnt during training and experience on-the-job. However, given the fact that controllers are constantly presented with a series of external events where no two situations are the same, such procedures must often be adapted during performance. In this regard, selective attention as the first stage becomes crucially important as controllers are expected to pay attention to specific sources of information that are relevant to the given situation (Wickens, et al., 1997). Working memory and long-term memory influence the way in which this selected information is perceived, and what controllers expect or anticipate about the event. Verbal working memory forms a critical component of communications within ATC as controllers are expected to retain information in the form of words or digits from a given request or read-back in order to manage the situation effectively. Controllers are also required to form a spatial representation of the three-dimensional airspace (i.e. location of aircraft) which is based on the two-dimensional radar display or written information presented on FPS, temporarily retained in working memory (Wickens et al., 1997).

Information in working memory is further interpreted on the basis of knowledge or schemas stored in long-term memory. Where the information obtained matches stored schemas (of a familiar situation), controllers are able to make predictions and respond appropriately. This process involves both comprehension and prediction, and thus provides a mental picture of the current situation and thus overall situation awareness. According to Wickens et al. (1997) situation awareness becomes crucially important as controllers are required to make predictions based on this mental picture.

According to this model, a controller's long-term memory, which contains important knowledge structures, further assists in the comprehension of situations (Wickens et al., 1997). Similar to the notion of mental models presented earlier, such knowledge structures consist of, for example: ATC procedures; equipment used; aircraft capabilities; and characteristics of the airspace. Knowledge stored in long-term memory therefore assists in decision-making which consists of knowledge gained through training (e.g. degree of separation required under specific weather conditions) and experience (e.g. risks associated with particular actions or situations) or observation of others where heuristics (familiar decision routines) or informal strategies are formed. In the context of unfamiliar situations, determining an appropriate action may require greater cognitive effort, where future consequences must be perceived (Wickens et al., 1997).

The cognitive function of decision making is expanded within this model as decision making may require a future plan of action, or series of actions, as opposed to immediate action. Where this is the case, controllers rely on prospective memory which refers to '... the ability to remember to take a particular action at a point in time in the future' (Wickens et al., 199, p. 96). Prospective memory is further used as a means for controllers to confirm the results of their actions - such as monitoring the altitude of aircraft which had previously been directed to a new flight level. Such memory is aided by reminders in the ATC environment, in particular the use of FPS (Wickens et al., 1997).

The individual cognitive effort required of controllers presents another determining factor of performance. According to Wickens et al. (1997), the amount of cognitive resources available to controllers is dependent on the nature of events. Where the frequency of events within a given time period, as well as the complexity of events is high, controllers will experience an increase in cognitive workload. The degree to which events are expected and routine further influences performance. Where controllers are able to detect a future conflict it may be treated according to routine procedures, depending on the level of experience of the individual controller and event rate. In the case of unexpected events such as an unanticipated arriving aircraft, or a change in flight path, extra cognitive effort may be required so as to enable the controller to incorporate the event within his or her current mental picture of the airspace (Wickens et al., 1997).

The nature of events has further been said to determine whether controllers apply rule-based versus knowledge-based behaviour (Wickens et al., 1997). Where events are familiar to the controller, rule-based behaviour is likely to be employed; whereas when presented with unfamiliar events (which are also highly complex in nature), knowledge-based behaviour and creative problem solving is required. It must, however, be noted that the extent to which rule-based as opposed to knowledge-based processing is applied to complex events is largely dependent on the level of expertise of the individual controller. For instance, when faced with the same level of complexity, an expert may apply rule-based behaviour whereas a novice may rely on knowledge-based behaviour (Wickens et al., 1997).

Strategies stored in long-term memory are also related to the way in which controllers are able to maintain a constant level of cognitive effort when faced with highly complex events without expending too many resources (Wickens et al., 1997). Heuristics and strategies stored in long-term memory may, for instance, assist controllers in perception, planning and action execution, as well as the allocation of perceptual attention among external events with high event rates. Strategies may also assist controllers to prioritise tasks when faced with high workload such as dealing with high priority tasks first (Seamster, Redding, Cannon, Ryder, & Purcell, 1993).

Having identified the role of controllers and tasks typically performed on-the-job and the importance of cognitive processes which enable controllers to perform within this complex environment, it is necessary to identify the role of ATC training in ensuring this is achieved.

2.3. Training in ATC

Wickens et al. (1997, p.72) highlight the importance of training to future controller performance by stating that '... full-performance-level controllers are produced by the training system'. Realising the importance of the training process to ensuring future controller performance is achieved; the International Civil Aviation Organisation (ICAO) has specified the standards and recommended practices of air traffic control training (detailed in Annex 1) (Skybrary, 2015).

According to the ICAO, controllers are expected to meet a number of specific requirements pertaining to the minimum age in which they may be issued a licence to operate (21 years of age), as well as medical fitness, knowledge and experience. The training process takes approximately two to three years where trainees undergo both theoretical and simulation based training at a training academy, and thereafter familiarisation and on-the-job training (OJT) at the operational unit concerned (Skybrary, 2015).

The ICAO refers to the initial training phase as ATCO Common Core Content Initial Training. The training consists of theoretical subjects and typically takes place over eight to twelve weeks. The theoretical subjects that controllers are required to complete are further stipulated by ICAO and consist of the following: general knowledge of the principles of flight; navigation; air traffic control equipment; meteorology; air law; language; and human performance and limitations. However, the actual content of a training plan and the time allocated to the individual subjects is determined the particular Air Traffic Service organisation or ANSP. The initial training therefore varies according to the subjects and topics adopted by the organisation concerned. For instance, Eurocontrol's specification for the ATCO Common Core Content Initial Training (in accordance with the provisions of Commission Regulation (EU) No 805/2011 of 10 August 2011) has adopted nine theoretical and practical based subjects in addition to the subjects stipulated by ICAO (Eurocontrol, 2008). Similar differences in training have been adopted by the FAA (Skybrary, 2015) and other ANSPs across the world, including South Africa (verbal communication with ANSP, 2014).

The main objective of the initial training phase is to prepare ATCOs (air traffic control officers), referred to in the current study as ATC trainees, for future training within an ATC unit. Initial training is achieved through two processes namely; basic training and rating training. Basic training involves the development of the knowledge and skills which allow trainees to progress to the specialised training phase. Specialised training takes place during the rating training which specifically focuses on imparting the knowledge and skills required within a job category and discipline pursued in the Air Traffic Service organisation i.e. tower, area or radar control (Skybrary, 2015).

After the initial training phase, trainees enter unit training which consists of three training processes namely; transitional training, pre-on-the-job training (Pre-OJT) and on-the-job training (OJT). Transitional training involves the process by which site-specific theoretical knowledge is transferred to the trainee. During this training ATC trainees are placed at an operational unit/facility for two to three months during which trainees are supervised (by the local training unit) where trainees experience the air traffic control environment and perform elementary/assistant tasks. These skills are further developed through specialised training within a chosen discipline (e.g. within tower, radar or area control) which is completed after approximately eight weeks of simulation training (Skybrary, 2015).

Trainees then return to the operational unit/facility to start unit training where they commence with pre-on-the-job training (Pre-OJT). The aim of Pre-OJT is to enhance the development of previously acquired routines and abilities at site-specific facilities. Trainees then enter the last stage of unit training which involves on-the-job training (OJT) where previously acquired job-related routines are integrated with further skills developed within live traffic situations under the supervision of a qualified on-the-job training instructor. OJT may take from six months to a year, depending on the ATC facility concerned. Thereafter, trainees are issued with a licence to operate within the given facility (Skybrary, 2015).

Continuation training is an important aspect within ATC where even once qualified, controllers are required to partake refresher training and emergency training. Refresher training is specifically aimed to review, upgrade or reinforce existing knowledge and skills of controllers required on-the-job. Emergency training serves as an important aspect of continuation training where it allows for the imparting of knowledge and skills that controllers require in the handling of unusual or degraded situations e.g. violation of ATC rules, human error or technical system failure (Eurocontrol, 2008; Skybrary, 2015). Furthermore, controllers wishing to advance or change positions within the Air Traffic Service organisation or ANSP are required to undergo development or conversion training which is aimed at providing the relevant knowledge and skills, as well as the procedures relevant to the new position and facility concerned (Eurocontrol, 2008; Skybrary, 2015).

The phases of a typical ATC training process are further illustrated in Figure 8 below. It is, however, important to note that the process of training which has been outlined presents a typical ATC training program and therefore may vary according to the ANSP (subject to ICAO standards and recommendations).

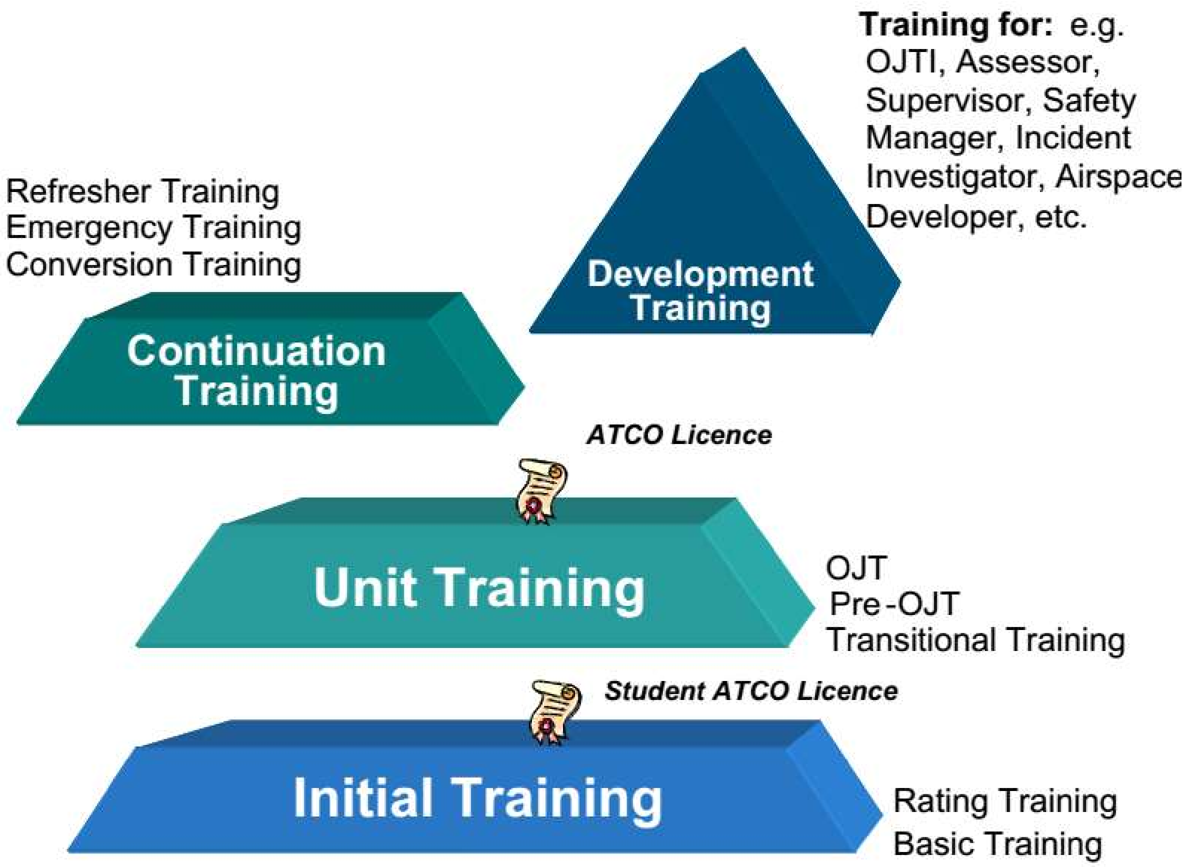

Figure 8. Progression of ATCO Training (Eurocontrol, 2008, p.10).

ATC training has been an important area of interest for over fifty years where researchers and Air Traffic Service organisations have continually strived to enhance the training process (Wickens et al., 1997). However, high standards of ATC training have not always translated to high success rates in training performance. A central problem to ATC training has been the number of trainees performing poorly during or failing to complete the training (e.g. Fox, 2014; Manning, Kegg & Collins, 1988; Salden, Paas, Boers & Van Merriënboer, 2004), as well as the high level of attrition both during and after training (e.g. Carretta & King, 2008). Manning et al. (1998, p.1) identify one of the reasons being that '... not all individuals have aptitudes required to perform the duties required of an ATCS.'

In response to Manning et al.'s (1998) and similar explanations for poor training performance, the ability to identify and screen for characteristics that predict trainee performance has been a major area of interest. Identifying such aspects is in fact crucial given the safety-related aspects of ATC, but in addition to this, the costs associated with training. According to Conzelmann & Keye, 2014, p. 2) '...training of ATCs is highly specific and cost-intensive reaching easily half a million Euros for each trainee until the end of training.'

Cognitive ability has been the most researched area in predicting ATC trainee performance beginning in the 1950's (Wickens et al., 1997). Cognitive abilities relating to arithmetic reasoning, abstract reasoning, and spatial abilities were amongst the first characteristics identified as predictive of trainee performance (Collins, Boone & Deventer, 1980; Hatting, 1991). More recent developments have identified cognitive abilities based on job analyses of controllers working on-the-job (Broach & Brecht-Clark, 1994). The cognitive abilities identified as predicting trainee performance consisted of: sensory/perceptual ability; verbal working memory; spatial working memory; long-term memory; and attention allocation. Spatial visualisation and reasoning abilities have also been identified as predictors of trainee performance by Ackerman and Kanfer (1993). In addition to mathematical, spatial and verbal cognitive abilities; perceptual speed has been identified as a powerful predictor of ATC trainee performance (Ackerman, Kanfer & Maynard, 1995). In more recent research, attention and memory have been associated with higher levels of training performance in both theoretical and practical elements within ATC training (Conzelman & Keye, 2014).

Although researchers have identified a number of non-cognitive factors such as personality (e.g. King, Retzlaff, Detwiler, Schroeder & Broach, 2003; Nye & Collins, 1991; Schroeder, Broach & Young, 1992), demographic, motivational and learning approaches (e.g.

Conzelman & Keye, 2014) contributing to ATC trainee performance; cognitive ability has remained a central predictor of trainee performance (Dean, Russel & Framer, 2002; Edgar 2002).

The central role of cognitive ability is perhaps emphasised by developments within ATC training which have come to differ from Manning et al.'s (1988) contention that individual aptitudes are the key predictors of performance. Instead, Bellorini et al. (1999) propose that ATC trainees are not likely to have experienced the extent of cognitive demands presented in ATC prior to their training. Realising this, Bellorini et al. (1999, p.2) argue that the cognitive complexity required on-the-job should be developed during training, stating that '... it is important to connect matters such as information processing activities, decision making, perceptive phenomena and capacity of memory to the tasks of ATC...' A Computer Based Training (CBT) approach for ATC trainee development, called MemPAC has been introduced to the training program in Europe which focuses on addressing the ability of trainees to recognise the mechanisms and limitations of the cognitive processes involved in ATC tasks. MemPAC focuses specifically on cognitive processes of memory, perception cognition, and attention. MemPAC was developed based on a performance analysis conducted by the States of the European Civil Aviation Conference (ECAC) which specifically identified the need to introduce these aspects to the training program. The aim of MemPAC is to increase the ability of ATC trainees to recognise the basic mechanisms and limitations of the cognitive processes involved in ATC tasks (Bellorini et al., 1999).

The cognitive functions identified in the ATC training literature clearly align with many of the cognitive functions that have been identified as crucial to controllers' ability to perform tasks on-the-job (Eurocontol, 1996; Wickens et al., 1997) as outlined earlier in this Chapter. It can therefore be said that cognitive processes not only play a crucial role in controller performance on-the-job, but also during training, whether identified as an individual aptitude or ability which can be developed.

Having considered the role of ATC and ATC training, it is evident that the performance of controllers is heavily reliant on a range of inputs and cognitive functions. The focus of this research, however, was to determine whether visual analysis is related to performance during training. However, it is important to understand that visual analysis would function within the context of the abovementioned cognitive processes and would therefore only account for a portion of trainee performance.

2.4. Visual Analysis

Intensive visual analysis has been identified in a number of occupations, most notably: closed circuit television (CCTV) surveillance operators; X-ray screeners in aviation; and radiologists (Andrew et al., 2003; Department for Transport, 2003; Donald, F. 2011; Donald, 1998b; Halbherr, Schwaninger, Budgell & Wales, 2013).Operators within these occupations perform visually demanding tasks which are often taxing on cognitive and perceptual resources as they are expected to detect infrequent signals or events occurring within high levels of background clutter (McCarley, Kramer, Wickens, Vidoni & Boot, 2004). In addition, operators are often expected to perform under highly stressful conditions and severe time constraints (Donald, F. 2011). The concept of visual analysis has primarily emerged due to the fact that the performance of operators has often been less than optimal in a number of industries where visual detection of significant events is important (Donald, 2011).

The advancement of imaging technologies being introduced to these industries have enabled operators to perform more effectively with regards to the detection of significant events (Donald, 1998; Donald, F. 2011). However, these technologies have presented new challenges for operators given that they are tasked with viewing displays characterised by content which '... moves from the real to the representative where graphic processing creates artificial colouring, changes image composition and removes or enhances only certain content which meets specific wavelength properties' (Donald, 2011, p.1). Although such technologies have been a major advancement toward ensuring a level of efficiency within these industries, the role of the human operator however, cannot be overlooked as they are still expected to identify problems or threats and analyse information presented by these displays/images. Such technological advancements have therefore demanded an increasing sophistication of visual analysis ability from operators (Donald, 2011).

Visual analysis has been associated with simplistic recognition, matching or memory recall (Donald, 1998). Donald (2011) argues that unlike simple recognition or matching activities, tasks which require visual analysis (e.g. security surveillance) rely on specific interpretation requirements implicit within these imaging technologies. The complexity of interpretation required is further determined by the degree to which the representative image diverges from the original item in composition, form and shape (Donald, 2011). The context in which events occur has also been identified as important where visual analysis is required, as it provides important information with which to identify the threat and subsequently determines the particular monitoring strategy adopted by operators. For instance, the detection of a threat, or what is considered as highly suspect behaviour in one context, will differ from another context where such behaviour may be regarded as normal (Donald, 2011).

Some of the elements of visual analysis required within visually demanding environments have been identified in human factors research. For instance, detection has been examined by visual search and eye movement research (Nodine & Krupinski, 1998; Wickens & McCarley, 2008; Wolfe, 1994). Situation awareness has been identified within detection research as crucial to an operator's understanding and ability to detect critical events relevant to a given situation (Sandom, 2001). Vigilance research has also identified the role of arousal or 'physiological efficiency' in determining an operator's ability to remain alert to critical events within the operational environment (Parasuraman, 1984). Although human factors research has highlighted important elements which may influence the way in which operators approach visually demanding tasks, it is however important to note that the cognitive visual analysis processes that are required to perform these tasks has not yet been established. This problem extends to previous research which has exclusively focused on the output of visual analysis as opposed to the cognitive processes which may be involved during visual analysis (Lowe, Hoffman, DeLong, Patz & Coleman, 1994).

Individual factors also influence performance on tasks requiring visual analysis. It is possible that one of these individual factors is visual analysis, however, future research is needed to evaluate the extent to which this is an inherent ability versus one that can be developed (Donald, 2011). Regardless of its origins, however, if visual analysis is required to perform certain tasks, it therefore seems logical to employ individuals with stronger visual analysis abilities or skills.

Although the importance of visual analysis in certain occupations has been recognised, the concept itself has not been investigated in its own right. Based on a study of CCTV surveillance operators, Donald, F. (2011, p. clxxvii) provided a definition of visual analysis as '... the active, goal-directed and effortful scrutiny of visual scenes in order to identify differences, discrepancies and patterns in objects, behaviours and events.' The current study sought to contribute to this area of research by investigating the role of visual analysis within the context of ATC.

2.4.1. Visual Analysis in Air Traffic Control

The visually demanding tasks required of ATC have been examined in previous research concerning the distribution of visual attention within ATC (Ellis, 2006; Metzger & Parasuraman, 2006). Visual attention has typically been determined by examining controller scanning which is measured by eye fixations, dwell time and movements across controller workstations (Metzger & Parasuraman, 2006). The Federal Aviation Administration (FAA) defines visual scanning as '... a systematic and continuous effort to acquire all necessary visual information in order to build and maintain a complete awareness of activities and situations which may affect the controllers' area of responsibility' (Stein, 1992, p.3).

Research examining the visual tasks performed by tower controllers has identified that tower controllers are mostly reliant on the view outside the tower (Ellis, 2006). Pinksa and Bourgois (2007) observed controllers via video and analysed their activity allocation at Warsaw Frederic Chopin Airport. They reported that the view outside the tower window was the major activity according to frequency and duration of visual behaviour. These findings are consistent with a study of tower observations recorded from an international airport (Oehme & Schulz-Rueckert, 2010). However, it should be noted that the amount of visual attention allocated within the tower may be determined by the technology available within the facility concerned. According to Oehme and Schulz-Reuckert (2010), the degree to which these systems assist and provide reliable information to controllers, determines the extent to which they depend on visual sightings from the tower window. The increase in air traffic and low visibility due to weather conditions has in fact demanded the development of technologies, such as instrumental information and sensor-based data. These enable controllers to work without such constraints and decrease the amount of attention allocated to the tower window (Oehme & Schulz-Rueckert, 2010).

On the other hand, the predominant use of radar displays has been observed by research examining the distribution of visual attention within the remaining two facilities; area and radar control (Karsten, Goldberg, Rood & Sultzer, 1975; Metzger & Parasuraman, 2006). Willems and Truitt (1999; as cited in Wickens et al., 1997) who conducted a study on visual attention amongst controllers reported that when examining fixations across the work space, 80% were on the radar display, 13% on FPS, and 5% on other input devices. Such findings have been confirmed even with the introduction of newer technologies to the ATC system.

For instance, Metzger and Parasuraman (2006) examined the introduction of the data link (digital communication as opposed to radio telephony) and predicted that the visual scanning of the radar display and other sources of information would be affected by this new technology. However, the results confirmed that a large proportion of visual attention was still focused on the radar display. According to Metzger and Parasuraman (2006), such findings are consistent given that conflict detection – which is the most important task performed by controllers - is determined by the information presented on radar displays.

Having outlined the role of ATC, including the tasks typically performed by controllers, together with the abovementioned research pertaining to visual scanning, it is evident that a significant portion of the tasks performed by controllers are in fact visual. Therefore, the current study argues that visual analysis should be considered as an important part of controllers' repertoire of skills. This is supported by research identifying a number of errors in ATC being attributed to controllers failing to perceive critical information presented on radar displays (Stein, 1989; Stein 1992), or simply failing to recognise and understand 'what is going on' and thus being unable to respond appropriately (Wickens et al., 1997). Such errors have remained despite the increased use of automation technologies which have been implemented to assist controllers in managing increased air traffic (Wickens et al., 1997).

Given the severity of consequences associated with errors in ATC, determining the possible reasons why controllers fail to take in and process visual information has been an area of interest. The Federal Aviation Administration (FAA) introduced a Controller Information Scanning program in 1988 which aimed at establishing how controllers search for and utilise the numerous sources of visual stimuli they are presented with on-the-job (Stein, 1989). Visual scanning has remained an area research and has developed throughout the years with advances in technology enabling researchers to examine visual scanning (through eye-movements) more closely so as to determine how controllers obtain the information they require (e.g. Stein, 1989; Stein, 1992).

Stein (1992) argues that the scanning process influences decision making and planning and thus these errors may be due to a breakdown in the scanning process where a critical event is missed, resulting in faulty decision making. Redding, Ryder, Seamster, Purcell & Cannon (1991) argue that such errors may be due to a lack of attention and active processing of this information, resulting in the poor identification and misuse of information, as opposed to a case of decreased visual scanning. Visual analysis is likely to be a vital skill in the detection process (forming part of the perception process), as well as influencing the ability to make accurate detections. This is consistent with Stein (1992) who reported that such errors may have been related to inaccurate visual analysis providing faulty inputs to situation awareness and thus resulting in faulty decision making. Based on Donald F.'s (2011) definition of visual analysis; this process extends beyond merely perceiving or sensing scenes, and involves an intentional, active analysis and effortful scrutiny of visual information. This supports Redding et al.'s argument (1991) that a lack of attention and information processing can lead to errors. In summary, the current study proposes that visual analysis, which involves both the accurate detection and effortful scrutiny of events, may be a factor contributing to certain errors within ATC.

Visual scanning research has also further examined controller performance according to their level of experience. Stein (1992) identified significant differences in visual scanning activity between novices and experts, with experts performing at a higher level. Similarly, van Meeuven (2015) concluded that the visual scanning approach adopted by controllers differed according to three levels of experience namely; experts, intermediates and novices. These findings were based on eye-movements recorded whilst controllers performed on-the-job typical ATC tasks. Based on such findings, the current study examined whether there is a difference in visual analysis scores (ScreenX and SAMAE) between trainees and qualified controllers.

The current study argues that whilst visual scanning research is useful in indicating where attention might be focused, it does not necessarily equate with visual analysis. Eye movement and scanning research does not provide information about the analytical processes that are being conducted while the eye is fixated on a particular area. It is possible that the controller is looking at a particular area in a display without actively perceiving or interpreting the information. Thus it can be argued that previous research (e.g., Stein, 1989; 1992) has sought to establish how controllers are able to obtain the information they require to perform on the job, but has largely failed to investigate the contribution of individualised image processing skills required in ATC (Donald, 2011).

Visual analysis may be relevant to ATC when considering that controller performance is based on complex visualisations of moving aircraft, including their labels containing crucial information (e.g., call sign, speed and heading) presented on radar displays. Given the abstract nature of the radar display, in which the three-dimensional airspace is presented on a two dimensional screen, and where aircraft are represented in the form of tags on the screen, visual analysis may be necessary given the interpretation requirements implicit within these displays. However, such interpretation is also demanded of controllers within tower control who largely depend on sightings outside the tower window. As in the case of radar and area controllers who rely on radar display, tower controllers rely on visual sightings from the tower in order to detect potential problems. The current study therefore proposes that visual analysis extends beyond analysing of visual displays, but also visual scenes and events.

2.5. Aim and Hypotheses:

The main aim of this study was to determine whether visual analysis exercise scores (ScreenX and SAMAE – Scanning and Division of Attention) are related to performance during training. The main aim was further broken down into specific hypotheses for the training course examined in this study.

Hypothesis 1: The visual analysis exercise scores (ScreenX and SAMAE – Scanning and Division of Attention) are related to performance during the Core Content course.

Hypothesis 2: There is a difference in visual analysis exercise scores (ScreenX and SAMAE – Scanning and Division of Attention) between trainees and qualified controllers.

CHAPTER 3: METHODOLOGY

This chapter describes the methodology used for the current study. In this section the research design, sample, research procedure, analysis methods, and ethical considerations are presented.

3.1. Research Design

The research design used for this study was quantitative, cross-sectional and non-experimental between-subjects. A quantitative design was employed for this study as it involved examining the relationship between visual analysis as an independent variable and performance (training results) as a dependent variable. Quantitative research involves the collection of numerical data and the subsequent analysis of this data using statistical methods of analysis (Stangor, 2011). A quantitative approach is concerned with drawing statistical conclusions about the relationships in an objective and quantifiable manner.
There was no random selection or random assignment and the independent variable was not manipulated in any way. No experimental or control group was present, hence no strong causal conclusions or inferences could be made in this study. This study aimed to examine the relationship between the variables under investigation – visual analysis and performance during training. Specifically, whether there is a relationship between the visual analysis exercises scores (ScreenX and SAMAE – Scanning and Division of Attention) and performance during the Core Content course. Non-experimental designs are useful for descriptive purposes as they can be used to develop theories, identify problems with current practices, or to justify current practices. These studies are also advantageous as they are inexpensive, time efficient and easy to implement (Stangor, 2011).

3.2. Sample

A total of 91 individuals participated in the research. Non-probability convenience sampling was used as responses were obtained from those participants who were willing and available to take part in the research (Stangor, 2011).

The number of participants who participated in each of the visual analysis exercises is presented in Table 2 below. Of the 91 participants, 88 were assessed for the ScreenX exercise. For the SAMAE exercise, 89 were assessed for Scanning and 91 for Division of Attention. The number of participants varied on the ScreenX and Scanning exercises due to time constraints or technical difficulties during the testing session concerned.

Table 2. Number of participants assessed by visual analysis exercises **(N=91)**

	N	%
ScreenX	88	96.7
Scanning	89	97.8
Division of Attention	91	100.0

Of the 91 participants, 51 were male and 40 were female (Table 3). The age of participants ranged from 19 to 51, with a mean age of 27. Most participants fell between the ages of 25 to 30 (Table 3).

The first language of participants varied within the sample (Table 3). Twenty-five participants were English; eleven Afrikaans; ten isiZulu; ten Sotho; eight Tsonga; six Setswana; six Sepedi; five Venda; three French; two Creole (French); two Siswati; and one Swahili.

Table 3. Number of participants based on gender, age and language (N=91)

	Frequency	Number of participants (%)
Gender		
Male	51	56.0
Female	40	44.0
Total	91	100.0
Age		
19-24	33	36.7
25-30	41	45.6
31-36	7	7.8

		Frequency	Number of participants (%)
Age			
37-42		5	5.6
43-48		2	2.2
49-54		2	2.2
Total		90	100.0
Age Mean (SD)	27.24 (6.65)		
Language			
English		25	27.5
Afrikaans		11	12.1
Tsonga		8	8.8
Setswana		6	6.6
isiZulu		10	11.0
Sotho		10	11.0
Sepedi		6	6.6
Venda		5	5.5
Swahili		1	1.1
Siswati		2	2.2
Xhosa		2	2.2
French		3	3.3
Creole French		2	2.2
Total		91	100.0

The degree to which participants were experienced in air traffic control varied as the sample consisted of sixty-one local trainees, five international trainees and twenty-five qualified controllers (Table 4). Participants were approached from an Air Navigation Service Provider (ANSP) in South Africa. Both local and international trainees were drawn from the ANSP's Training Academy (61); whereas nine qualified controllers were drawn from International

Airport A, six from International Airport B, six from Airport C, and four from Airport D (Table 4).

Table 4. Number of participants based on job and unit/airport

	Frequency	Number of participants (%)
Job		
Trainee	61	67.0
International Trainee	5	5.5
Qualified Controller	25	27.5
Total	91	100.0
Unit/Airport		
Academy	66	72.5
International Airport A	9	9.9
International Airport B	6	6.6
Airport C	6	6.6
Airport D	4	4.4
Total	91	100.0

The trainees who participated in the research were at various stages of the training process. It must be noted that even though the participants were assessed by the visual analysis exercises at one point in time during the research, they did however continue to advance to other stages within the training process throughout this period, whilst some trainees were already at the advanced stages of training when they were assessed. The individual trainee reports obtained for the training courses varied for each of the participants due to some participants having withdrawn from the course concerned and some who were at different stages of training. The number of trainee reports was also reliant on the availability of data from the ANSP as some reports were no longer available on record. Thus, the training results for each of the courses are presented in Table 5 below, according to the availability of course reports.

Of the ninety-one participants, forty-five Core Content course reports were obtained, whilst nine participants withdrew from the course. Thirty-five Service Assistant Rating course reports were obtained; four Assistant Rating Coordinator course reports; and twelve Aerodrome Readiness and Clearance Delivery course reports. Seven reports were obtained for the Aerodrome Control course, whilst two participants withdrew from the course. And lastly, three participant course reports were obtained for the Aerodrome Advanced course. It must however be noted that the amount of trainees obtained per subject for each of the courses varied. Participants who had withdrawn from the relevant course, but had completed some of subjects for each of the courses, were included in the main analysis. In addition, the number of participants per subject also varied due to changes in course curriculum where some subjects had been removed or added to the course concerned.

Table 5. Number of Course reports obtained

	Frequency (n=91)	**Percentage of Participants (%)**
Core Content Course	45	49.5
Withdrew	9	9.9
Service Assistant Rating	35	38.5
Service Assistant Rating Coordinator	4	4.4
Aerodrome Readiness & Clearance Delivery	12	13.2
Aerodrome Control Course	7	7.7
Withdrew	2	2.2
Aerodrome Control Advanced	3	3.3
Total	91	100.0

In addition to sixty-one South African (local) trainees, the sample included five international trainees who completed international courses. Experts from the ANSP commented that the courses attended by local and international trainees were different, and therefore these trainees were treated as different sub-samples in terms of training course results.

3.3. Procedure

Prior to assessments taking place, a task analysis of the visual skills which ATCs require in order to carry out their tasks was determined. This process required two visits to the ANSP which involved observing ATCs on-the-job and during training. Discussions also took place with the organisation's trainers and human factors personnel, as well as an examination of relevant documentation such as: training manuals (relevant to the different courses) and job descriptions.

The second step of the research process required administering the visual analysis exercises, ScreenX and SAMAE (Scanning and Division of Attention), to trainees (including international trainees) and qualified controllers. It is noted that even though the participants were assessed on the visual analysis exercises only once, the point in their training at which this took place varied due to practicalities. Some trainees were assessed near the beginning of their first training course and others at a later stage. Some had already continued to more advanced courses in the overall training process after the visual analysis assessments. The reason for this is that a limited number of trainees enter training each year, and there was a need to obtain as large a sample as possible. However, results were mostly analysed per training course, specifically the Core Content course, restricting effects of the variations in the timing of the visual analysis assessments.

Visual analysis assessments took place at times and places that were convenient to the organisation and participants. No qualified controllers completed the exercises before their shift as this could have increased their fatigue and increased safety risks on-the-job. Participation in the study was voluntary and consent from participants was obtained prior to any assessments taking place. Participants signed consent forms allowing the organisation to release their training course reports to the researcher. The researcher provided participants who requested feedback with an overview of their visual analysis exercise results.

The visual analysis assessments took place at two types of venues. First, both local trainees and international trainees completed the visual analysis exercises (ScreenX and SAMAE) at the organisation's training academy. Second, qualified controllers were assessed in an office situated at the aerodrome where they worked at the different airports. The sample of qualified controllers includes controllers who work at all three facilities namely; tower, area and radar control.

3.4. Measuring Instruments

3.4.1. Demographic questionnaire

A demographic questionnaire (Appendix D) was administered to participants specifying: their name; nationality; first language; position/grade; gender; and highest education level. This information was only used for descriptive purposes.

3.4.2. Visual analysis exercises

Three computer-based visual analysis exercises were used - SAMAE which consisted of two exercises called Scanning and Division of Attention, and ScreenX. These exercises were used with the permission of Leaderware cc.

SAMAE

SAMAE is a comprehensive assessment consisting of two subset exercises; the Scanning exercise and Division of Attention exercise. SAMAE was specifically designed to evaluate the ability of CCTV surveillance operators to perform consistently and effectively, and has further been extended to other visually intensive occupations. This assessment evaluates the ability to maintain vigilant, rapidly detect, identify and react to anomalies or incidents, as well as to analyse and process visual information on a sustained level (Donald, 1998a).

The Scanning Exercise is characterised by a moving object that is compared with a standard object that is present at all times. Target objects change in various ways at any time. These objects must be constantly compared to the standard image (which allows individuals to constantly be aware of the requirements) where positioning of object, colour, rotation, loss of information and the ability to analyse the entire object is evaluated. This exercise specifically '... evaluates a person's ability to rapidly scan a situation and detect a range of subtle to obvious deviations from the defined standard' (Donald 1998b, p.3). It lasts for thirty minutes.

The Scanning exercise consists of measures of detection, reaction time and false alarms. The exercise contains two detection measures recording the percentage of target items correctly detected within four and fifteen seconds of them being displayed. The four-second score reflects the speed of visual analysis and the identification of anomalies or inconsistencies in a situation. If this happens in less than four seconds, the person is said to have an immediate feel for the situation and is able to “home in” on key issues (Donald, 1998b). The fifteen-second score indicates the same detection skill, but allows more time for detection. This measure indicates a thorough and persevering approach rather than just speed. Reaction time is measured in seconds and reflects the rate of change of the individual’s response time during the exercise. The speed of response time indicates quicker and more efficient visualising, memory and general information processing skills. Effectively it shows the person’s speed of homing in on inconsistent details in a situation. The false alarm measure refers to the detection of target items when no target item was present. The lack of ability to recognise key features, differences, and inconsistencies in the way things relate to one another will result in false alarms. This could indicate poor judgement without an appropriate level of insight, or guessing (Donald, 1998b).

The Division of Attention exercise consists of several objects which simultaneously change and move around according to random paths at specific intervals. Individuals are required to detect changes in perspective, speed and colour, as well as the visual presence of objects through prioritising their attention effectively and constantly tracking such changes (Donald, 1998b). The exercise evaluates ‘the ability to effectively monitor and deal with a situation where attention must be allocated to independent and changing sources of information’ (Donald, 1998a, p.1). It lasts for thirty minutes.

The Division of Attention exercise consists of three measures: detection, reaction time, and false alarms. Detection is measured by the percentage of target items correctly detected within four-seconds of them being displayed. Unlike the scanning exercise, if people do not detect an item change within four seconds it is not likely to be detected at all. The detection score is important in that it shows how aware the person is during the exercise and how consistently they can pick up the changes in items. It shows the ability to track multiple objects at once, use of peripheral vision, the sharing of attention between various priority issues, and the capability to handle a situation characterised by extensive movement. Reaction time was measured in seconds. This indicates the sensitivity of the person to changes in a dynamic situation. Faster times indicate greater tracking skills and sensitivity to change in such situations. The false alarm measure reflects a response to a change that did not occur with that object (Donald, 1998a).

Acceptable reliability of SAMAE has been reported with Kuder Richardson reliability coefficients for the Scanning Exercise at .83 and the Division of Attention Exercise at .86 (Donald, 1998b)

ScreenX

ScreenX is an adapted version of Leaderware's SAMAE assessment. The ScreenX exercise requires individuals to observe the repositioning of an object on the screen which may change at any time. The image must constantly be compared to a standard image in order to observe whether there are different elements within the object. Such elements may include the positioning of objects, rotation, colour, and loss of information (Leaderware, 2013). The ScreenX assessment evaluates '... how quickly someone can rapidly scan a situation and detect a range of subtle to obvious deviations from defined standards which includes identifying anomalies in the scene' (Leaderware, 2013, p. 2). As ScreenX is only a 10-minute assessment, its main focus is on the power of detection as opposed to sustained concentration over extended periods of time which SAMAE assessments allow for (Leaderware, 2013).

The ScreenX exercise consists of three different detection measures, a reaction time measure and false alarms measure (Leaderware, 2013). Detection is measured according to the percentage of target items correctly detected within four, six, and eight-seconds of them being displayed. The four-second score is important for environments where detection of inconsistencies of anomalies must occur extremely quickly. The six-second score shows high speed detection (requiring the same detection skills as the four-second measure), but allows the individual to assess the situation for a slightly longer period of time. The eight-second measure, like the six-second measure allows for detection to take place over a longer time period, however still requires the detection skills measured by the four-second measure. Reaction time is measured in seconds, with faster response times indicating quicker visual analysis speeds. The false alarm measure reflects the detection of target items when no target item was present. This measure indicates where individuals have not positively identified items before responding (Leaderware, 2013).

Based on validation information, ScreenX correlates well with SAMAE (Leaderware, 2013).

3.4.3. Training course results

In order to determine whether visual analysis is related to performance during training, the current study utilised training results based on the Core Content course reports. The Core Content course was selected as the performance measure for training due to the availability of data across all of the course subjects. The Core Content course is the first training course which all aspiring air traffic controllers are required to attend. The Core Content course covers fifteen theoretical subjects (except for one having an additional practical component) which form the foundation of air traffic control (Table 6). The measure of training performance used for the current study was therefore based on the results presented in the Core Content course reports (from the ANSP) for each of the participants in the study who had attended the course or at least some of the Core Content course subjects. The course reports listed each of the fifteen subjects which contained percentages per subject and a percentage for overall participant performance. The pass rate as indicated by the reports required trainees to obtain a mark of 70% for each subject of which they could be reassessed for only two subjects which fell below this mark, failing to do so resulted in withdrawal from the course. The overall average required to pass the course was 70%.

Table * Core Content course subjects and description (taken from ANSP)

Subject	Description
ICAO Organisation, Procedures and Documents	To provide the student with knowledge of the International Civil Aviation Organisation (ICAO), planning processes, procedures, documents and the skills to amend selected documents.
ATC / Aim Theory and Procedures Section A	To provide the student with knowledge of the Air Traffic Services and Aeronautical Information Management and skills in order to apply these in the execution of their duties in the operational environment.
ATC / Aim Theory and Procedures Section B	To provide the student with knowledge of the Air Traffic Services and Aeronautical Information Management and skills in order to apply these in the execution of their duties in the operational environment.
Aerodrome Physical	To provide the student with knowledge of the physical layout, charts, markings and services associated with an aerodrome to be applied during more specific and specialised training and eventually during the provision of Air Traffic Services.
Aircraft Identification and Performance	To enable the student to identify the various types of aircraft and classify their performance.
Principles of Flight	To provide the student with an understanding of the principles of flight and the forces acting on aircraft in flight in order to apply these during further training and in the execution of their duties in the operational environment.
Meteorology	To equip the student with knowledge of various meteorological phenomena, as well as the content of a meteorological briefing from documentation supplied by the meteorological office and to prepare such documentation, in order to function as meteorological observers.
Navigation and Maps	To provide the student with knowledge of navigation, maps, charts and plotting to be applied in conjunction with Alerting service and ATM/CNS system concepts.
Avionics	To equip the student with knowledge regarding specific aspects of avionics related to terrestrial and airborne equipment to ensure the ability to apply the knowledge of the various systems in the operational environment.
Aviation Legislation	To provide the student with knowledge of the development and hierarchy of aviation legislation and associated documentation in order to apply these in the execution of their duties in the operational environment.
Subject	Description
Search and Rescue	To equip the student with an understanding of the search and rescue organisation and the detailed operation thereof in order to apply these in the execution of their duties as an assistant in a Rescue Co-ordination or Sub-centre.

Instrument and Approach Procedures and Area Navigation	To provide the student with knowledge in order to understand and interpret the concepts, functions and types of instrument procedures in order to apply this in the execution of their duties in the operational environment.
Aerodrome Physical	To provide the student with knowledge of the physical layout, charts, markings and services associated with an aerodrome to be applied during more specific and specialised training and eventually during the provision of Air Traffic Services.
ATM/CNS	To provide the student with knowledge of the ATM/CNS system principles and concepts and applications in order to apply this in the execution of their duties in the operational environment.
Safety Management and Human Factors	To equip the learner with the necessary skills and attitudes to understand the importance of human factors in the ATS environment.
Aeronautical Messaging Practical	To enable the student to understand the drafting, addressing, typing and despatching of messages on the AFTN tele-printer, and computer (PC) with minimum errors and at tempo that will satisfy operational requirements.

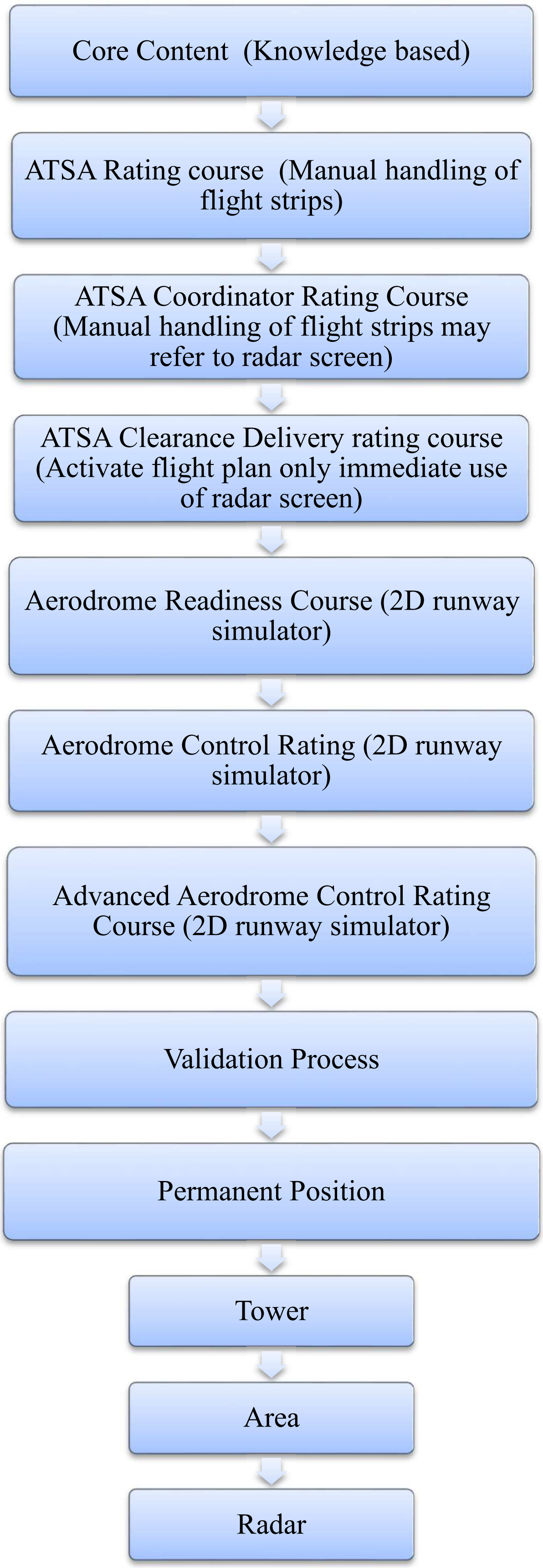

Figure 9. Flow diagram of training process composed from ANSP training schedule.

3.5. Method of Analysis

3.5.1. Main analysis

Descriptive statistics were run in order to determine the nature of participant responses. The descriptive statics used specifically were means, frequencies, standard deviations, minimums and maximums, and skewness tests to assess normality of the data. Descriptive statistics were used to classify, summarise, and describe the quantitative data obtained.

To establish whether there was a relationship between the visual analysis exercise scores (SAMAE and ScreenX) and performance during the Core Content course, a Pearson's correlation coefficient analysis was used. A correlation analysis is typically used to examine the relationship between the variables of interest (Huck, 2012). Although a correlation cannot provide information as to why the variables of interest may be related, it does however fulfil the aim of the current study, which is to explore the relationship between these variables (Stangor, 2011).

The correlation coefficient enables one to measure the strength of the relationship between the variables and is a point on a scale ranging from -1 to +1. A stronger relationship between the variables exists when the correlation coefficient is closer to either -1 or +1 (Howell, 2004). A positive relationship is represented by a positive number where, an increase in one variable is related to an increase in the other variable. Thus, where there is an increase in one variable and a decrease in the other variable, a negative relationship is said to exist (Howell, 2004).

In order for a Pearson's correlation coefficient procedure to be used, the assumptions of the parametric analysis must be satisfied. Prior to conducting the analysis, the assumptions for: normality; interval data; random independent sampling; and equality of variances were examined. An assessment of normality is a pre-requisite for many statistical tests such as linear regression because normal data is an underlying assumption in parametric testing (Howell, 2011). Normality was assessed via skewness where values lying between -1 and +1 were classified as normal. Thus, in the case where normality could not be determined, the non-parametric Spearman's rank correlation coefficients procedure was used.

A linear regression procedure was used as a second statistical analysis in order to examine whether the visual analysis exercise scores (SAMAE and ScreenX) predict performance during the Core Content course. Given the large number of variables in the study, regressions were only calculated for relationships that were significant in the correlations.

The regression procedure is used to predict or explain the relationship between variables of interest (Huck, 2012). The regression coefficient/standardised estimate enables one to observe whether a positive or negative relationship exists between the variables of interest. A positive sign indicates a positive relationship, where an increase in one variable is related to an increase in the other variable. And where an increase in one variable is associated with a decrease in the other variable, a negative relationship exists (Howell, 2004). The R score further enables one to observe the strength of the relationship between these variables. In addition, by observing the adjusted R-square value, representing the coefficient of determination, enables one to identify the extent to which variability among the scores on the dependent variable has been explained or accounted for by the independent variable (Huck, 2012).

A number of assumptions had to be satisfied in order for linear regressions to be used in the current study namely: random sampling; interval data; normality; evidence of linearity; outliers identified; homogeneity of variance; and multicollinearity (Huck, 2012). All of the above listed assumptions were met for the current study.

3.5.2. Secondary analyses

An additional analysis was carried out to determine whether there was a difference in the visual analysis scores across three sub-samples: local trainees, international trainees and qualified controllers. T-tests and one-way ANOVAs were used as they allow for the comparison between two or more group means of the dependent variable according to the independent variables (Huck, 2012). One-way ANOVAs and T-tests were therefore used to determine whether there is a difference between the mean visual analysis scores (SAMAE and ScreenX) for three sub-samples. The assumptions for the tests were considered prior to analysis such as; normality, interval data, and random independent sampling. Where these assumptions were not met, non-parametric analyses were used.

3.6. Ethical Considerations

The research was approved by the ethics committee of the University of the Witwatersrand (Appendix A). Permission from the ANSP was obtained prior to conducting the research. In order to ensure the interests of the organisation were protected, a non-disclosure agreement was signed by the researcher.

Participants were given a covering letter (Appendix B) outlining the purpose of the research, its expected duration, and the procedures that would be employed, as well as their right to decline to participate in the study or to withdraw from the study before or during assessments. Thereafter, participants were given a consent form (Appendix C) where they consented to participate in the research. Although participants were informed of the research by managers and instructors, participation was voluntary. Consent was granted from the relevant ANSP to access trainee course reports.

Anonymity could not be assured as demographic information including the name and contact details of participants were recorded in order to link visual analysis exercise scores and course reports to respective participants. However, this information remained confidential as only the researcher had access to this information. The research required one and a half hours per participant. Due to the length of time, participants were given breaks between the assessments. The assessments were carried out in a quiet environment. The researcher was available at all times to answer questions, as well as to assist with any problems. Participants were provided with clear instructions of how to respond to the given task, were given the opportunity to practice, and to ask questions. The participants were not advantaged or disadvantaged in any way as only group trends were reported in the research as opposed to individual results. The identity of the organisation was also not disclosed. After completion of the study, participants were given the appropriate feedback which also allowed for participants to contact the researcher for any queries pertaining to the results of the research. The participating organisation (ANSP) was provided with an executive summary and a full report of the results.

CHAPTER 4: RESULTS

This chapter presents the results of the current study. The main aim of the study was to establish whether there is a relationship between the visual analysis exercise scores (ScreenX and SAMAE – Scanning and Division of Attention) and performance during training. The first section of this chapter presents the descriptive statistics for the visual analysis exercises. This is followed by addressing Hypothesis 1 of the study regarding the relationship between the visual analysis exercise scores (ScreenX and SAMAE – Scanning and Division of Attention) and performance during the Core Content Course. A brief description of the subjects for the Core Content course is provided with the aim of orienting the reader to the course. It also explains the rationale for potential relationships between visual analysis scores and Core Content course results. This is followed by the descriptive statistics for the Core Content course results. Thereafter, the correlations and linear regressions based on each of the visual analysis exercises are presented. Thus, a sub-section is devoted to each visual analysis exercise and its relationship with the relevant subjects within the Core Content course. Hypothesis 2 of the current study is thereafter addressed - whether there is a difference in visual analysis exercise scores (ScreenX and SAMAE – Scanning and Division of Attention) between trainees and qualified controllers. This was specifically examined according to each of the three sub-groups: local trainees, international trainees, and qualified controllers on the visual analysis exercises. Finally, a summary of the results is provided at the end of this chapter.

It is noted that linear regressions were only performed where correlations between the visual analysis exercises and Core Content subjects were significant. Significance was at the .05 level. However, where significance was less than .01, this was reported. The number of trainees per subject varies on the Core Content course as some of the trainees who withdrew from the course did not complete all of the subjects. A pass mark of 70% was required for all subjects on the course.

4.1. Descriptive Statistics for Visual Analysis Exercises

The measures from the visual analysis exercises include detection measures (i.e. correct detection rate or percentage of hits), reaction times, and false alarms for each of the three exercises; ScreenX and SAMAE (i.e. Scanning and Division of attention). The detection measures consisted of the percentage of target items correctly detected within four, six, eight or fifteen-seconds of them being displayed, depending on the measure used by the specific exercise. For ScreenX, target items were displayed for up to eight-seconds, and for Scanning the maximum period was fifteen-seconds. Reaction time was measured in seconds. The false alarm measure reflects reports of target items when no target item was present. Descriptive statistics for the visual analysis exercises for the entire sample are presented in Table 7 below.

Table 7. Descriptive statistics of visual analysis exercises

Visual Analysis Exercise	**Variable**	**Mean**	**SD**	**Min**	**Max**
ScreenX	4s Detection	29.74	11.23	0.00	56.51
(N=89)	6s Detection	43.08	13.25	0.00	75.61
	8s Detection	51.63	13.20	0.00	82.93
	Reaction time	3.82	6.80	0.00	5.76
	False alarms	1.74	2.17	0.00	14.00
Scanning	4s Detection	48.10	14.33	9.52	83.33
(N=89)	15s Detection	76.97	10.61	42.86	95.24
	Reaction time	3.99	1.00	1.87	6.64
	False alarms	3.40	5.74	0.00	29.00
Division	4s Detection	59.39	11.81	23.61	83.33
(N = 91)	Reaction time	2.03	0.26	1.59	2.85
	False alarms	10.63	22.06	0.00	179.00

4.1.1. Descriptive statistics for ScreenX

The mean number of targets detected over the four-second detection measure for ScreenX was 29.74% (Table 7). The *SD* of 11.23 indicates that most participants detected between 18.51% and 40.97% of target items. The mean increased over the longer time periods, with detections over six-seconds presenting a mean of 43.08% of targets, where most participants detected between 29.85% and 58.33% based on a *SD* of 13.25. The detection score over eight-seconds presented a mean of 51.63%, with a *SD* of 13.20 indicating that between 38.43% and 64.83% of targets were detected by participants. The mean reaction time was 3.82seconds, with a *SD* of 6.80 indicating that most of the participants' reaction times fell between3.14and 4.5 seconds. And lastly, a mean of 1.74 and *SD* of 2.17 for false alarms was reported.

4.1.2. Descriptive statistics for SAMAE: Scanning

The mean detection over four-seconds was 48.10% (Table 7). A *SD* of 14.33 indicates that most of the participants detected between 33.77% and 62.43% of the target items. The mean number of targets detected over fifteen-seconds was 76.97%, with a *SD* of 10.61 indicating that most participants detected between 66.36% and 87.58% of the target items. The mean reaction time was 3.99 seconds. A *SD* of 1.00 indicates that most participants' reaction times fell between 2.99 and 4.99 seconds. The mean false alarm rate was 3.40. A fairly high *SD* of 5.74 suggests large individual variability on this measure.

4.1.3. Descriptive statistics for SAMAE: Division of Attention

The mean detection over four-seconds was 59.39% (Table 7). A *SD* of 11.81 indicates that most participants detected between 47.58% and 71.2% of the target items. The mean reaction time was 2.03 seconds. A *SD* of 0.26 indicates that most of the participants responded between 1.77 and 2.29 seconds. The mean number of false alarms was 10.63, with a very large *SD* of 22.06 indicating high variability between individuals on this measure.

4.2. Descriptive Statistics for the Core Content Course

As mentioned in the previous chapter, the Core Content course covers fifteen theoretical subjects which form the foundation of air traffic control. Examples include: Aviation Legislation (e.g. separation standards for different sectors of the airspace); Aircraft Identification and Performance (e.g. capability of aircraft); Meteorology (e.g. weather conditions); Aeronautical Messaging Practical (communications with pilots); and other subjects that are essential to understanding and managing the airspace (see Table 6 in Chapter 2). Based on this array of subjects, trainees are required to form a mental representation of the airspace or runway which reflects their understanding. It is argued that visual analysis is related to the ability to form an accurate mental representation of the airspace or runway, and that there should be a relationship between the visual analysis exercise scores and performance on the subjects. However, this relationship is likely to be weak because the course is largely theoretical. This stands despite the inclusion of some practical elements included in the assessments where trainees are presented with a scenario (e.g. manage aircraft within particular weather conditions) in which they are required analyse and make appropriate decisions based on recalling the theory learnt during the course (e.g. type of aircraft, rules of the air).

In this section descriptive statistics for the Core Content course are presented, followed by correlations and regressions based on each of the visual analysis exercises.

The performance for the Core Content course is examined according to the marks obtained for each of the fifteen subjects making up the course and an overall average mark for the course. Table 8 presents the mean performance for the Core Content course where the number of trainees is presented, as well as the mean percentage obtained, *SD* and range of scores for each of the subjects.

Table 8. Descriptive Statistics of Core Content Course

N	Subject	Mean	SD	Min	Max	Skewness	Kurtosis
45	Navigation and Maps	89.41	6.65	70.00	99.00	-1.03	1.19
45	Aeronautical Messaging Practical	89.03	9.43	70.00	100.00	-0.78	-0.52
47	Aircraft Identification and Performance	87.39	6.87	66.60	100.00	-0.71	0.73
47	Principles of Flight	86.22	7.73	65.00	96.60	-1.07	0.84
50	Aerodrome Physical	85.61	8.63	56.00	96.00	-1.64	2.97
46	Instruments and Approach Procedures and Area Navigation	85.13	5.72	74.00	94.00	-0.39	-1.16
45	Safety Management and Human Factors	83.51	7.61	68.00	98.00	-0.11	-1.07
51	ICAO Organisation, Procedures and Documents	83.43	8.79	57.00	97.00	-1.01	1.38
48	ATM/CNS	83.10	9.67	54.30	98.70	-0.68	0.09
49	Aviation Legislation	82.95	7.72	62.00	94.00	-0.82	0.26
46	Avionics	81.02	8.91	64.00	98.00	-0.06	-0.86
47	Meteorology	79.53	8.24	54.00	96.00	-0.37	0.53
49	Search and Rescue	78.39	11.23	48.00	94.00	-0.71	0.18
44	ATC Theory and Procedures Section B	74.05	7.27	54.00	93.00	-0.08	1.10
45	ATC Theory and Procedures Section A	71.36	9.55	45.00	89.00	-0.40	0.43
44	Average	83.30	4.51	74.50	90.90	-0.26	-0.78

On the Core Content Course, the subject with the highest mean was Navigation and Maps (*M*= 89.41). A *SD* of 6.65 indicates that most of the trainees obtained a mark between 82.77% and 96.05% for the subject. The next highest subject was Aeronautical Messaging Practical (*M*=89.03%, *SD*=9.43). The lowest marks were obtained for ATC Theory and Procedures Section A (*M* =71.36%, *SD*=9.55). A mean of 83.30 % was obtained based on the overall average mark reported for each individual trainee who attended the Course. A *SD* of 4.51

indicates that trainees obtained an overall average between 78.79% and 87.81% for the Core Content course.

Based on the minimum marks obtained on the course, there were twelve subjects that one or more trainees failed. The subjects that all trainees passed were: Navigation and Maps; Aeronautical Messaging Practical; and Instruments and Approach Procedures and Area Navigation. Results for re-assessments were excluded from the analysis.

4.3. ScreenX's Relationship to Core Content Course results

This section presents the correlations and regressions for Hypothesis 1 regarding the relationship between the ScreenX exercise scores and performance during the Core Content Course. Pearson's correlations were carried out for 14 of the subjects, including the overall average mark for the course. The data for the Aerodrome Physical subject was significantly skewed (Table 8), violating the assumption of normality and thus required a Spearman's correlation coefficient procedure as a non-parametric equivalent. However, no significant results were found between ScreenX and Aerodrome Physical. Pearson correlations between ScreenX and the Core Content course subjects are presented in Table 9.

Table 9. Pearson correlation coefficients for ScreenX and Core Content Course

ScreenX Score	ICAO Org, Proc & Docs	ATC Theory & Proc Sec A	ATC Theory & Proc Sec B	Aircraft ID & Performance	Principles of Flight	Meteorology	Navigation & Maps	Avionics	Aviation Legislation	Search & Rescue	Instruments & Approach	ATM/CNS	Aeronautical Messaging	Safety Manage & HF	Average
4s Detection	.18	.13	.27	.34*	.30*	.25	.14	.26	.25	.07	.23	.20	.03	.20	.27
N	51	45	44	47	47	47	45	46	49	49	46	48	45	45	44
6s Detection	.23	.16	.31*	.37*	.38**	.35*	.24	.29*	.26	.16	.38**	.39**	.01	.21	.36*
N	51	45	44	47	47	47	45	46	49	49	46	48	45	45	44
8s Detection	.22	.11	.33*	.32*	.43**	.37**	.15	.32*	.26	.11	.37*	.40**	-.02	.18	.31*
N	51	45	44	47	47	47	45	46	49	49	46	48	45	45	44
Reaction time	.24	-.18	-.22	.13	.04	-.05	-.10	-.15	-.06	.01	-.18	.27	-.01	-.19	-.22
N	51	45	44	47	47	47	45	46	49	49	46	48	45	45	44
False alarms	-.12	-.17	-.18	.03	-.18	.05	.05	-.25	.04	.09	-.02	.04	-.12	-.08	-.15
N	51	45	44	47	47	47	45	46	49	49	46	48	45	45	44

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

ScreenX results show a significant relationship between the 4-second detection score and two of the Core Content subjects: Aircraft Identification and Performance (r=.34, $p<.05$) and Principles of Flight (r=.30, $p<.05$). The positive relationship suggests that high detection rates within the first four seconds of a target appearing on the display are associated with high levels of performance in these two subjects. However, the correlation coefficients are moderate.

The ScreenX 6-second detection measure seemed to be more useful as it correlated significantly with seven subjects (as opposed to two subjects for the 4-second measure). These were: ATC Theory and Procedures Section B (r=.31, $p<.05$); Aircraft Identification and Performance (r=.37, $p<.05$); Meteorology (r=.35, $p<.05$); Avionics (r=.29, $p<.05$); Principles of Flight (r=.38, $p<.01$); Instruments and Approach Procedures and Area Navigation (r=.38, $p<.01$); and ATM/CNS (r=.39, $p<.01$). In addition to this, the 6-second detection measure correlated significantly with overall average for the Core Content course (r=.36, $p<.05$). These relationships for the ScreenX 6-second detection measure are moderate with the exception of Avionics which is weak.

Similarly, to the 6-second detection measure, the ScreenX 8-second detection measure correlates significantly with seven of the subjects namely: ATC Theory and Procedures Section B (r =.33, $p<.05$); Aircraft Identification and Performance (r=.32, $p<.05$); Avionics (r=.32, $p<.05$); Instruments and Approach Procedures and Area Navigation (r =.37, $p<05$); Principles of Flight (r =.43, $p<.01$); Meteorology (r =.37, $p<.01$); and ATM/CNS (r=.40, $p<.01$. The 8-second detection measure also correlated significantly with the overall average for the Core Content course (r= .31, $p<.05$). These correlations range from moderate (r=.32) to strong (r=.43). The strongest relationships are between the 8-second detection score and ATM/CNS (r =.40) and Principles of Flight (r=.43). It is noted that no causal explanation can be made between these variables despite significant relationships being found.

There were no significant correlations for reaction times or false alarms for ScreenX, indicating that these are not related to the Core Content Course subjects. In addition, no significant correlations were found for any of the visual analysis measures for the Aerodrome Physical subject based on the Spearman's correlation procedure.

Linear regressions were calculated for the significant correlations between ScreenX and the Core Content Course subjects (Table 10).

Table 10. Regressions for ScreenX and Core Content Course

ScreenX Measure N	Subject	R-Square	Sig	Standardised Coefficients Beta
4s Detection 47	Aircraft Identification and Performance	.12	.02	.34
4s Detection 47	Principles of Flight	.09	.04	.30
6s Detection 48	ATM/CNS	.16	.01	.39
6s Detection 47	Principles of Flight	.15	.01	.38
6s Detection 46	Instruments and Approach Procedures and Area Navigation	.15	.01	.38
6s Detection 47	Aircraft Identification and Performance	.14	.01	.37
6s Detection 47	Meteorology	.13	.02	.35
6s Detection 44	ATC Theory and Procedures Section B	.10	.04	.31
6s Detection 46	Avionics	.09	.05	.29
6s Detection 43	Average	.13	.02	.12
8s Detection 47	Principles of Flight	.19	.00	.43
8s Detection 48	ATM/CNS	.16	.01	.40

ScreenX Measure N	Subject	R-Square	Sig	Standardised Coefficients Beta
8s Detection 47	Meteorology	.14	.01	.37
8s Detection 46	Instruments and Approach Procedures and Area Navigation	.14	.01	.37
8s Detection 44	ATC Theory and Procedures Section B	.11	.03	.33
8s Detection 47	Aircraft Identification and Performance	.11	.03	.32
8s Detection 46	Avionics	.10	.03	.32
8s Detection 43	Average	.10	.04	.11

Regressions revealed that the 4-second detection measure for ScreenX is a significant predictor of performance for Aircraft Identification and Performance (F (1, 45) = 5.83, p<.05; R^2 =.12) and Principles of Flight (F (1, 45) = 4.32, p<.05; R^2 =.09). The R-square values indicate that the ScreenX 4-second detection score accounts for a low percentage of the variance in performance for Principles of Flight at 9% and for ATC Theory and Procedures Section B (12%).

The 6-second detection score for ScreenX is a significant predictor of performance for: ATM/CNS (F (1,46) = 8.45, p< .05; R^2 =.16); Principles of Flight (F (1,45) = 7.78, p<.05; R^2 =.15); Instruments and Approach Procedures and Area Navigation (F (1, 44) = 7.57, p<.05; R^2 = .15); Aircraft Identification and Performance (F (1, 45) = 7.22, p< .05; R^2 =.14); Meteorology (F (1,45) = 6.46, p< .05; R^2 =.13); ATC Theory and Procedures Section B (F (1, 42)= 4.58, p<.05; R^2 =.10); and Avionics (F (1, 44) = 4.09, p<.05; R^2 =.09). The R-square values indicate that the 6-second detection measure accounts for a relatively small percentage of the variance in performance for all seven subjects ranging from 9% (ATM/CNS) to 15%

(Principles of Flight). The 6-second detection score was also a significant predictor of the overall average for the course (F (1, 42) = 6.145, p<.05; R^2=.13). However, it accounted for a relatively small percentage of the variance in the overall average achieved on the course (13%).

The analysis revealed that the 8-second detection score for ScreenX is a significant predictor of performance for seven subjects: Principles of Flight (F (1, 45)= 10.32, p< .05; R^2 =.19); ATM/CNS (F (1,46) = 8.49, p < .05; R^2 =.16); Meteorology (F (1, 45)= 7.31, p< .05; R^2 = .14); Instruments and Approach Procedures and Area Navigation (F (1,44)= 6.9, p< .05; R^2 = .14); ATC Theory and Procedures Section B (F (1, 42) = 5.18, p< .05; R^2 =.11); Aircraft Identification and Performance (F (1, 45) = 5.286, p< .05; R^2 =.11); and Avionics (F (1, 44) = 5.13, p< .05; R^2 =.10).The 8-second detection score explains from 10 to 19% of the variance, with the largest percentage explained for Principles of Flight. Similar to the 6-second score, the 8-second detection score was also a significant predictor of the overall average for the Core Content course (F (1,42) = 4.48, p<.05; R^2 =.10), although accounting for a slightly smaller percentage of the variance than the 6-second score (10%).

In summary, the 6-second and 8-second detection measures for ScreenX appear to be the most useful measures as they are each related to seven of the fifteen subjects, as well as the overall average for the Core Content course, as opposed to the 4-second detection measure which is only related to two of the subjects. The strongest predictors were based on the 8-second detection measure. However, they only provided a very slight increase in the variance compared to the 6-second detection measure. Overall, ScreenX scores contributed from 9 to 19% of the variance on seven subjects for the Core Content course and the overall average for the course.

4.4. SAMAE: Scanning's Relationship to the Core Content Course Results

This section presents the correlations and regressions for Hypothesis 1 regarding the relationship between the Scanning exercise scores and performance during the Core Content Course. No significant results were found based on the Spearman's correlation analysis between the Scanning exercise and Aerodrome Physical. Pearson correlations between the Scanning exercise and the Core Content course subjects are presented in Table 11.

Table 11. Pearson correlation coefficients for Scanning and Core Content Course

Scanning Score	ICAO Org, Proc & Docs	ATC Theory & Proc Sec A	ATC Theory & Proc Sec B	Aircraft ID & Performance	Principles of Flight	Meteorology	Navigation & Maps	Avionics	Aviation Legislation	Search & Rescue	Instruments & Approach	ATM/CNS	Aeronautical Messaging	Safety Manage & HF	Average
4s Detection	.41**	.25	.20	.17	.32*	.32*	.13	.44**	.51**	.16	.12	-.02	.02	.06	.22
N	51	45	44	47	47	47	45	46	49	49	46	48	45	45	44
15s Detection	.22	.24	.12	.18	.21	.13	.16	.20	.49**	.23	.17	.16	.12	.13	.19
N	51	45	44	47	47	47	45	46	49	49	46	48	45	45	44
Reaction time	-.37**	-.19	-.27	-.04	-.36*	-.35*	-.07	-.49**	-.46**	-.10	-.1	.17	.06	-.04	-.19
N	51	45	44	47	47	47	45	46	49	49	46	48	45	45	44
False alarms	-.02	-.16	-.11	-.18	-.01	.05	-.09	-.26	.11	.06	-.07	-.07	-.31*	-.10	-.24
N	51	45	44	47	47	47	45	46	49	49	46	48	45	45	44

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

For the Scanning exercise, there is a significant relationship between the 4-second detection score and five of the subjects: ICAO Organisation, Procedures and Documents; Principles of Flight; Meteorology; Avionics; and Aviation Legislation (Table 11). The results indicate that high detection rates over the four-second period are associated with high levels of performance in each of these subjects. These relationships range from moderate (Principles of Flight r=.32; p<.05; Meteorology r=.32, p<.05) to strong (ICAO Organisation, Procedures and Documents r=.41, p<.01; Avionics r=.44, p<.01; and Aviation Legislation r=.51, p<.01). For the 15-second detection score, there was only one significant positive correlation with Aviation Legislation (r=.49, p<.01).

The Scanning reaction time measure correlated significantly with five of the Core Content subjects: ICAO Organisation, Procedures and Documents (r= -.37, p<.01); Principles of Flight (r= -.36, p<.05); Meteorology (r = -.35, p<.05); Avionics (r= -.49, p<.01); and Aviation Legislation (r= -.46, p<.01). All these correlations are negative; thus longer reaction times are associated with lower levels of performance in each of the five subjects. The relationships varied from moderate to strong.

The False alarm measure for the Scanning exercise correlated significantly with only one subject, Aeronautical Messaging Practical (r= -.31, p< .05). The negative correlation indicates that a high number of false alarms are associated with lower levels of performance for this subject; however, they are weakly related.

Linear regressions were calculated for the significant correlations between the Scanning exercise and the Core Content course subjects (Table 12).

Table 12. Regressions for Scanning and Core Content Course

Scanning Measure N	Subject	R-Square	Sig	Standardised Coefficients Beta
4s Detection 49	Aviation Legislation	.26	.00	.51
4s Detection 46	Avionics	.19	.00	.44
4s Detection 51	ICAO Organisation, Procedures and Documents	.16	.00	.41
4s Detection 47	Principles of Flight	.10	.03	.32
4s Detection 47	Meteorology	.10	.03	.32
15s Detection 49	Aviation Legislation	.24	.00	.49
Reaction time 46	Avionics	.24	.00	-.49
Reaction time 49	Aviation Legislation	.21	.00	-.46
Reaction time 51	ICAO Organisation, Procedures and Documents	.14	.01	-.37
Reaction time 47	Principles of Flight	.13	.01	-.36
Reaction time 47	Meteorology	.13	.02	-.35
False alarms 45	Aeronautical Messaging Practical	.10	.04	-.31

The results revealed that the Scanning 4-second detection measure is a significant predictor of five Core Content subjects: Aviation Legislation (F (1, 47) = 16.67, p<.05; R^2 = .26); Avionics (F (1,44) = 10.33, p< .05; R^2 =.19); ICAO Organisation, Procedures and Documents (F (1,49) = 9.61, p< .05; R^2 =.16); Principles of Flight (F (1,45) = 5.2, p<.05; R^2 = .10); and Meteorology (F (1,45) = 5.12, p< .05; R^2 =.10). However, the R-square values indicate that the Scanning 4-second detection measure predicted a relatively small percentage of the variance in performance for most of these subjects, ranging from 10 to 26%.

The results suggest that the Scanning 15-second detection measure is a significant predictor of performance for Aviation Legislation (F (1, 47) = 14.54, p< .05; R^2 =.24), with 24% of the variance in performance for this subject being explained by this measure.

Scanning's reaction time measure is a significant predictor of five subjects on the Core Content course: Avionics (F (1,44) = 13.645, p<.05; R^2 = .24); Aviation Legislation (F (1,47) = 12.35, p<.05; R^2 =.21); ICAO Organisation, Procedures and Documents (F (1,49) = 7.916, p<.05; R^2 =.14); Principles of Flight (F (1,45) = 6.849, p<.05; R^2 =.13); and Meteorology (F (1,45) = 6.46, p<.05; R^2 =.13). The R-square values indicate, however, that Scanning's reaction time measure does not explain much of the variance as it ranges from 13 to 24%.

The Scanning false alarm measure is a significant predictor of performance for the Aeronautical Messaging Practical subject (F (1, 43) = 4.68, p<.05; R^2 =.10), however it accounts for a relatively small percentage (10%) of the variance in performance.

In summary, the Scanning 4-second detection measure seemed to be more useful than the 15-second detection measure as it predicted performance in five of the subjects in comparison to the 15-second detection measure which only predicted one subject. The reaction time measure predicted performance for the same five subjects as the 4-second detection measure. The detection and reaction time measures contributed from 10 to 26% of the variance in performance on these subjects, with the largest percentages being for Aviation Legislation and Avionics. The false alarm measure does not appear to be a useful measure in predicting performance for the Core Content course.

4.5. SAMAE: Division of Attention's Relationship to the Core Content Course Results

This section presents the correlations and regressions for Hypothesis 1 regarding the relationship between the Division of Attention exercise scores and performance during the Core Content Course. No significant results were found based on the Spearman's correlation analysis between the Division of Attention exercise and Aerodrome Physical. Pearson correlations between the Division of Attention exercise and the Core Content course subjects are presented in Table 13.

Table 13. Pearson correlation coefficients for Division of Attention and Core Content Course

Division of Attention Score	ICAO Org, Proc & Docs	ATC Theory & Proc Sec A	ATC Theory & Proc Sec B	Aircraft ID & Performance	Principles of Flight	Meteorology	Navigation & Maps	Avionics	Aviation Legislation	Search & Rescue	Instruments & Approach Proc	ATM/CNS	Aeronautical Messaging	Safety Manage & HF	Average
4s Detection	.19	.21	.22	.10	.17	.48**	.20	.26	.26	.27	.00	.17	-.11	.22	.21
N	51	45	44	47	47	47	45	46	49	49	46	48	45	45	44
Reaction time	-.17	-.20	-.18	-.18	.01	-.35*	.08	-.31*	-.05	-.05	-.02	-.09	-.03	-.03	-.14
N	51	45	44	47	47	47	45	46	49	49	46	48	45	45	44
False alarms	-.01	.04	.04	-.17	.00	-.11	-.14	-.02	-.07	.02	-.01	.01	-.12	-.01	-.13
N	51	45	44	47	47	47	45	46	49	49	46	48	45	45	44

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

For the Division of Attention exercise, there was a strong significant relationship between the 4-second detection measure and Meteorology (r = .48, p<.01) indicating that high detection rates are associated with higher levels of performance in this subject. Reaction time also correlated moderately and significantly with Meteorology (r= -.35, p<.01), as well as Avionics (r= -.31, p< .05). The negative relationships indicate that longer reaction times are associated with lower levels of performance in both Meteorology and Avionics.

Linear regressions were calculated for the significant correlations between the Division of Attention exercise and the Core Content course subjects (Table 14).

Table 14. Regressions for Division of Attention and Core Content Course

Division of Attention Measure N	Subject	R-Square	Sig	Standardised Coefficients Beta
4s Detection **47**	Meteorology	.23	.00	.48
Reaction time **47**	Meteorology	.12	.02	-.35
Reaction time **46**	Avionics	.10	.04	-.31

The Division of Attention 4-second detection score is a significant predictor of performance for Meteorology (F (1, 45) = 13.14, p<.05; R^2 =.23), and accounts for 23% of the variance in performance for the subject. Reaction time for the Division of Attention exercise is also a significant predictor of performance for Meteorology (F (1, 45) = 6.17, p<.05; R^2 =.12), as well as Avionics (F (1, 44) = 4.60, p< .05; R^2 =.10). However, reaction time accounts for a smaller proportion of the variance for both subjects at 12 and 10%.

4.6. Visual Analysis in Trainees versus Qualified Air Traffic Controllers

This section compares the visual analysis scores of trainees with qualified air traffic controllers (Hypothesis 2). The trainee sample included local and international trainees. Although both groups completed the visual analysis exercises, they attended different training courses with different requirements and therefore were treated as separate sub-samples. Before selecting the statistical test to analyse the data, the nature of the data was assessed in order to decide whether certain assumptions for the parametric tests were fulfilled. All of the dependent variables met the assumptions for interval data (continuous scale). They consisted of two or more independent, categorical groups; and observations were independent. Normality was established for most of the dependent variables, except for ScreenX's reaction time and the false alarm measures on all three of the visual analysis exercises (i.e. ScreenX and SAMAE – Scanning and Division of Attention) which required non-parametric analyses (Table 7). The Mann-Whitney U test and Kruskal-Wallis test were performed as non-parametric equivalents of the t-test and one-way ANOVA for these variables.

It is noted that the results for independent t-tests were reported according the Levene's Test for Equality of Variances. Where the significance value for *F* was greater than .05 equality of variances was assumed (i.e. indicating that the variability in the two conditions were not significantly different); whereas equality of variances was not assumed where significance was less than .05 (Howell, 2004).

In this section a comparison between local trainees and controllers on the ScreenX exercise scores is firstly presented. This is followed by a comparison between all three of the sub-groups: local trainees, international trainees and qualified controllers on both Scanning and Division of Attention exercise scores.

4.6.1. Comparison of local trainees and controllers on ScreenX scores

The international trainees were excluded from the ScreenX analysis due to their small sample size on this measure. The descriptive statistics on ScreenX scores for local trainees and controllers indicate that the largest differences in means between the two groups is for the 4-second detection measure (Table 15). The difference decreases for the detection measures over longer periods of time (i.e. 6-second and 8-second detection). Parametric analyses of these differences are presented next, followed by non-parametric analyses for ScreenX's reaction time and false alarm measures.

Table 15. Descriptive statistics on ScreenX scores for local trainees and controllers

ScreenX	Group	N	Mean	Std. Dev.	Std. Error
4s Detection	Local trainees	**61**	28.12	11.59	1.48
	Controllers	**25**	34.53	9.25	1.85
6s Detection	Local trainees	**61**	41.70	13.94	1.78
	Controllers	**25**	47.32	10.72	2.14
8s Detection	Local trainees	**61**	50.99	13.88	1.78
	Controllers	**25**	54.63	10.98	2.20

Table 16. T-tests on ScreenX scores between local trainees and controllers

		Levene's Test for Equality of Variances			
ScreenX		**F**	**Sig.**	**t**	**df**
4s Detection	Equality of Variances Assumed	.99	.32	-2.46*	84
6s Detection	Equality of Variances Assumed	1.55	.22	-1.80	84
8s Detection	Equality of Variances Assumed	.41	.52	-1.20	84

* Significant at the .05 level (2-tailed).

The t-test results indicate a significant difference on ScreenX's 4-second detection measure between local trainees and controllers (t (84) = -2.461, p< .05). The results indicate that controllers (M=34.53) detected significantly more targets than trainees (M=28.12) in the first four seconds of a target's appearance (Table 16).

The ranks for the Mann-Whitney U test on reaction time and false alarms for ScreenX indicate that local trainees have slower reaction times (i.e. required more time to respond) and reported more false alarms than controllers (Table 17).

Table 17. Descriptive statistics based on Mean Ranks on ScreenX's reaction times and false alarms for local trainees and controllers

ScreenX Group		N	Mean Rank	Sum of Ranks
Reaction time	Local trainees	61	47.52	2899
	Controllers	25	33.68	842
	Total	86		
False alarms	Local trainees	61	45.69	2787
	Controllers	25	38.16	954
	Total	86		

Table 18. Mann-Whitney U tests for reaction time and false alarms on ScreenX between local trainees and controllers

	ScreenX reaction time	ScreenX false alarms
Mann-Whitney U	517*	629
Wilcoxon W	842	954
Z	-2.34	-1.31
Asymp. Sig. (2-tailed)	.02	.19

* Significant at the .05 level (2-tailed).

The Mann-Whitney U test results (Table 18) found a significant difference in mean ranks for ScreenX's reaction time between local trainees and controllers ($U = 517$, $p<.05$), but not for false alarms. According to the mean ranks, local trainees ($M = 47.52$) showed a slower reaction time than controllers ($M = 33.68$) (Table 17).

4.6.2. Comparison of local trainees, international trainees and controllers on SAMAE: Scanning and Division of Attention scores

All three sub-samples: local trainees, international trainees and controllers were included in the analysis for SAMAE – Scanning and Division of Attention. The descriptive statistics on SAMAE scores for all three sub-samples indicate the largest differences in means between the groups for Scanning's 4-second detection measure (Table 19). The difference decreases over time based on Scanning's 15-second detection measure. The difference also decreases between the 4-second detection measures for Scanning and Division of Attention. Parametric analyses of these differences are presented next, followed by non-parametric analyses for Scanning and Division of Attention false alarm measures.

Table19. Descriptive statistics for local trainees, international trainees and controllers on SAMAE - Scanning and Division of Attention

SAMAE	Group	N	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean Lower	95% Confidence Interval for Mean Upper	Min	Max
Scanning: 4s Detection	Local trainee	59	47.54	13.92	1.81	43.91	51.17	9.52	76.19
	International Trainee	5	29.52	13.74	6.15	12.46	46.58	9.52	47.62
	Controller	25	53.14	12.42	2.48	48.02	58.27	33.33	83.33
Scanning: 15s Detection	Local Trainee	59	76.88	10.55	1.37	74.12	79.63	42.86	95.24
	International Trainee	5	62.38	8.65	3.87	51.64	73.13	50.00	71.43
	Controller	25	80.10	8.77	1.75	76.47	83.71	61.90	92.86
Scanning: Reaction time	Local Trainee	59	4.01	1.05	.14	3.74	4.29	1.87	6.64
	International Trainee	5	4.70	1.33	.59	3.05	6.35	3.63	6.49
	Controller	25	3.79	.75	.15	3.48	4.10	2.31	5.39
Scanning: False alarms	Local Trainee	59	3.54	6.12	.80	1.95	5.14	0.00	29.00
	International Trainee	5	7.60	9.24	4.13	-3.87	19.07	0.00	20.00
	Controller	25	2.24	3.31	.66	.88	3.60	0.00	16.00
Division of Attention: 4s Detection	Local Trainee	61	60.16	11.31	1.45	57.27	63.06	29.17	81.94
	International Trainee	5	41.39	11.34	5.07	27.30	55.47	23.61	51.39
	Controller	25	61.11	10.48	2.10	56.79	65.44	45.83	83.33
Division of Attention: Reaction time	Local Trainee	61	2.12	.27	.03	2.00	2.14	1.60	2.85
	International Trainee	5	2.12	.09	.04	2.01	2.23	1.98	2.22
	Controller	25	1.93	.25	.05	1.82	2.03	1.59	2.57
Division of Attention: False alarms	Trainee	61	10.72	14.78	1.89	6.94	14.51	0.00	82.00
	International Trainee	5	38.60	78.52	35.12	-58.99	136.10	1.00	179.00
	Controller	25	4.80	7.26	1.45	1.80	7.80	0.00	27.00

It is noted that the confidence intervals for the means for the international trainees tend to be large (Table 19). This is probably due to the small sample size (Howell, 2010), and indicates that results for this sub-sample should be treated with caution.

Table 20. One-way ANOVA for local trainees, international trainees and controllers on SAMAE – Scanning and Division of Attention

Exercise: Measure	Comparison type	Sum of Squares	df	Mean Square	F	Sig.
Scanning 4s Detection	Between Groups	2380.15	2	1190.08	6.52*	.00
	Within Groups	15694.42	86	182.49		
	Total	18074.57	88			
Scanning 15s Detection	Between Groups	1308.80	2	654.40	6.55*	.00
	Within Groups	8598.08	86	99.98		
	Total	9906.88	88			
Scanning Reaction time	Between Groups	3.61	2	1.81	1.85	.16
	Within Groups	83.98	86	.98		
	Total	87.59	88			
Division of Attention 4s Detection	Between Groups	1730.99	2	865.50	7.04*	.00
	Within Groups	10821.46	88	122.97		
	Total	12552.45	90			
Division of Attention Reaction time	Between Groups	.38	2	.19	2.79	.07
	Within Groups	5.93	88	.07		
	Total	6.31	90			

* Significant at the .05 level (2-tailed).

The one-way ANOVAs' results indicate significant differences between the sub-samples on Scanning's 4-second detection (F (2, 86) = 6.52, p<.05) and 15-second detection measures (F (2,86) = 6.55, p< .05); and Division of Attention's 4-second detection measure (F (2,88) = 7.04, p<.05) (Table 20).

Post hoc LDS tests identified which sub-samples differed significantly from each other on these measures (Table 21).

Table 21. Post hoc LSD tests of differences between local trainees, international trainees and controllers

SAMAE	Group comparison		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Scanning: 4s Detection	Local Trainee	International Trainee	18.02*	6.29	.00	5.51	30.52
		Controller	-5.60	3.22	.09	-12.01	.80
	International Trainee	Controller	-23.62*	6.62	.00	-36.78	-10.47
Scanning: 15s Detection	Local Trainee	International Trainee	14.49*	4.66	.00	5.24	23.75
		Controller	-3.22	2.39	.18	-7.96	1.52
	International Trainees	Controller	-17.71*	4.90	.00	-27.45	-7.98
Scanning: Reaction time	Local Trainee	International Trainee	-.69	.46	.14	-1.60	.23
		Controller	.23	.24	.34	-.24	.696
	International Trainees	Controller	.92	.48	.06	-.05	1.88
Division of Attention: 4s Detection	Local Trainee	International Trainee	18.78*	5.16	.00	8.52	29.03
		Controller	-.95	2.63	.72	-6.18	4.29
	International Trainees	Controller	-19.72*	5.43	.00	-30.52	-8.93
Division of Attention: Reaction time	Local Trainee	International Trainee	-.05	.12	.70	-.29	.19
		Controller	.14*	.06	.03	.02	.26
	International Trainees	Controller	.19	.13	.15	-.07	.44

* The mean difference is significant at the 0.05 level.

The post-hoc tests revealed that for Scanning's 4-second detection measure, local trainees (M=47.54) scored higher than international trainees (M=29.52); and controllers (M=53.14) scored higher than international trainees (M = 29.52). For Scanning's 15-second detection measure, local trainees (M =76.88) scored higher than international trainees (M=62.38); and controllers (M=80.10) scored higher than international trainees (M=62.38). On the Division of Attention 4-second detection measure, local trainees (M=60.16) scored higher than international trainees (M=41.39); and controllers (M=61.11) scored higher than international trainees (M=41.39).

The descriptive statistics on SAMAE scores for the sub-samples indicate the largest differences in means (mean rank) between the groups for the Division of Attention false alarm measure (Table 22). Non-parametric analyses using the Kruskal Wallis test were performed on the false alarm measures for both Scanning and Division of Attention and are presented below (Table 23).

Table 22. Mean ranks on false alarms for Scanning and Division of Attention for local trainees, international trainees and controllers

SAMAE: measure	Group	N	Mean Rank
Scanning: False alarms	Local Trainee	59	45.24
	International Trainee	5	54.50
	Controller	25	42.54
Division of Attention: False alarms	Local Trainee	61	51.26
	International Trainee	5	47.20
	Controller	25	32.92

There was a significant difference between the sub-samples on false alarms for Division of Attention ($X^2{}_2 = 8.62$, $p<.05$), but not for false alarms on Scanning ($X^2{}_2 = .95$, $p>.05$) (Table 23).

Table 23. Kruskal Wallis Test on false alarm measures for SAMAE – Scanning and Division of Attention for local trainees, international trainees and controllers

	Scanning: False alarms	Division: False alarms
Chi-Square	.95	8.62*
df	2	2
Asymp. Sig.	.62	.01

Significance at .05 level of significance.

The results for the Division of Attention exercise were further investigated using pair-wise comparisons. A significant difference between local trainees and controllers was found, with local trainees reporting a significantly higher number of false alarms (*M*=51.26) than controllers (*M*=32.92) (Table 24).

Table 24. Pairwise comparisons on Scanning's false alarms for local trainees, international trainees and controllers

Sample 1 – Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
Controller - International Trainees	14.28	12.90	1.12	.27	.80
Controller- Local Trainees	18.34	6.25	2.93	.00	.01
International Trainees –Local Trainees	4.06	12.25	.33	.74	1.00

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.

Asymptotic significances (2-sided tests) are displayed. The significance is .05.

4.7. Summary of Results

4.7.1. Main analysis

The results regarding the relationship between the visual analysis exercises and Core Content course results are summarised in Table 25.

Table 25. Summary results for relationship between the visual analysis exercises and performance on the Core Content course

	Visual Analysis Exercise Measure	Core Content Course	R-square
ScreenX	**4s Detection**	Aircraft Identification and Performance	.12
		Principles of Flight	.09
	6s Detection	ATM/CNS	.16
		Principles of Flight	.15
		Instruments and Approach Procedures and Area Navigation	.15
		Aircraft Identification and Performance	.14
		Meteorology	.13
		ATC Theory and Procedures Section B	.10
		Avionics	.09
	8s Detection	Principles of Flight	.19
		ATM/CNS	.16
		Meteorology	.14
		Instruments and Approach Procedures and Area Navigation	.14
		ATC Theory and Procedures Section B	.11
		Aircraft Identification and Performance	.11
		Avionics	.10
SAMAE – Scanning	**4s Detection**	Aviation Legislation	.26
		Avionics	.19
		ICAO Organisation, Procedures and Documents	.16
		Principles of Flight	.10
		Meteorology	.10
	15s Detection	Aviation Legislation	.24
	Reaction time	Avionics	.24
		Aviation Legislation	.21
		ICAO Organisation, Procedures and Documents	.14
		Principles of Flight	.13
		Meteorology	.13
	False alarms	Aeronautical Messaging Practical	.10
SAMAE – Division of Attention	**4s Detection**	Meteorology	.23
	Reaction time	Meteorology	.12
		Avionics	.10

4.7.2. Secondary analysis

Regarding the visual analysis scores of trainees compared with qualified controllers, controllers were able to perform faster and more accurate visual analysis than local trainees in the first four seconds of a target's appearance (international trainees were excluded from this analysis). For SAMAE's Scanning and Division of Attention exercises, there were no significant differences between local trainees and qualified controllers in terms of detection rates. However, controllers reacted more quickly than local trainees on the Division of Attention exercise and reported fewer false alarms on the Scanning and Division of Attention exercises. International trainees generally obtained the lowest scores on the visual analysis exercises, but these results should be interpreted with caution due to their low sample size.

CHAPTER 5: DISCUSSION

This chapter discusses the results of the current study. It begins with a brief re-statement of the rationale for the research and the reason for the proposal that visual analysis is important to air traffic control. This is followed by a discussion of the predictive ability of the visual analysis exercises to the Core Content course. Differences in visual analysis abilities between trainees and controllers are then discussed. This is followed by a discussion of the limitations of the study, recommendations for future research and the implications for future research.

The main aim of the study was to determine whether visual analysis exercise scores (i.e. ScreenX and SAMAE – Scanning and Division of Attention) are related to performance during training, specifically the Core Content course. Aspiring air traffic controllers are required to attend various training courses, some of which lead to ratings when combined with on-the-job training or validation. ATC training is expensive and time consuming due to a number of factors such as: safety considerations; international standards; the complexity of the job; and high levels of risk involved in the job. Although applicants are carefully selected using various tools and techniques, visual analysis has previously not been assessed in trainees or controllers. An understanding of the contribution of visual analysis abilities to performance during training could be used to enhance success rates of training and later, successful performance as qualified controllers.

5.1. Relevance of Visual Analysis to ATC

The relevance of visual analysis ability has been demonstrated in other visually demanding occupations (e.g. X-ray screening and CCTV surveillance) (Donald 1998). Given that the tasks of controllers rely extensively on the use of radar displays and other visual information, it has therefore been proposed that visual analysis could be relevant to air traffic control (Donald, 2011). As outlined in Chapter 2, the role of ATC is to manage aircraft within the airspace and on the ground in order to ensure safety and efficiency at all times (Wickens et al., 1997). To achieve this, controllers perform multiple tasks in a complex environment, relying on information from a number of different sources (Wickens et al., 1997). While some of the information is auditory (e.g. radiotelephony), other information is based on visual displays which may be graphic (e.g. radar, visual scans of runways) and/ alphanumeric in nature (Ellis, 2006; Metzger & Parasuraman, 2006; van Meeuwen, 2015). Certain controller errors have been attributed to controllers failing to perceive critical information presented on displays (Stein, 1989), and consequently failing to develop accurate situation awareness (Wickens et al., 1997). In this study it was proposed that visual analysis skills can contribute to the successful completion of training as a controller. Ultimately, visual analysis could also contribute to the successful performance of qualified controllers, but this was beyond the scope of the study.

5.2. Prediction of Core Content Course Results by Visual Analysis Exercises

Before discussing the results for the Core Content course, the reader is reminded that the course consisted of fifteen subjects which are all theoretically based (except for the Aeronautical Messaging practical component). The way in which each subject was assessed required trainees to provide a solution based on a scenario relevant to the ATC subject. In order to do so, trainees had to perform a thorough analysis and present an understanding of the given problem (identifying motives or causes, making inferences, and finding evidence to support generalisations) and evaluating information and potential solutions before making a decision. No simulator based assessments are conducted for this course. The Core Content course is the first course that aspiring controllers attend. The results are discussed for each visual analysis exercise, followed by an overview across the exercises for this course.

5.2.1. ScreenX and the Core Content course

The ScreenX exercise included detection scores over different time intervals (4, 6 and 8 seconds), and a reaction time and false alarm measure. The results revealed a significant positive relationship between the 4-second detection measure and two subjects - Aircraft Identification and Performance; and Principles of Flight. The 4-second measure accounted for a fairly low percentage of the variance on Aircraft Identification and Performance of 12%, and Principles of Flight of 9%. The short time period of four seconds suggests that efficient visual analysis is important in these subjects. This seems logical because trainees are expected to identify specific aircraft quickly and to analyse how specific aerodrome dynamics, presented in a given task, may affect the performance of specific types of aircraft (based on acquired knowledge) before attempting to provide a solution to the problem. It is likely that visual analysis provides one of the inputs to this process.

ScreenX's 6- and 8-second detection measures each showed a larger number of significant relationships with the Core Content course subjects than the 4-second measure. This was expected because these measures allowed more time for visual analysis to take place. The 6- and 8-second detection measures were significantly related to performance for the same subjects as the 4-second measure (Aircraft Identification and Performance; and Principles of Flight), plus an additional five subjects: ATM/CNS; Instruments and Approach Procedures and Area Navigation; Meteorology; Theory and Procedures Section B; and Avionics. In addition, both measures significantly related to the overall average for the course. Trainees who scored a high percentage of hits over the six and eight second period also obtained higher marks in these subjects and the overall average mark for the course. Regression analyses indicated that ScreenX's 6-second detection measure contributed from 9 to 16% of the variance on the above seven Core Content course subjects and Average for the course, whilst the 8-second detection measure provided a slight increase in the variance for the same subjects from 10 to 19%, except for the overall average for the course. Although less efficient than the 4-second measure, the 6- and 8-second measures require the same detection skills. These relationships may be explained according to the same reasoning as for the 4-second measure, where the ability to analyse a situation, to 'home in' on key issues and respond appropriately, requires trainees to identify particular aspects of the situation. Thus the ability to accurately identify (i.e. detect) aspects pertinent to the current situation forms an essential component of trainee performance and, as such, informs their ability to respond appropriately to the given situation, based on knowledge acquired during training. Examples of this include detecting surface speed of aircraft, decoding meteorology messages, detecting inappropriate messaging, and changes in weather conditions.

Considering the number of significant relationships and the strength of prediction across ScreenX's 4-, 6- and 8-second detection measures, it appears that the 6- and 8-second measures predict performance on the Core Content course more effectively than the 4-second measure. A possible explanation for this is that the 4-second measure requires trainees to respond too quickly to targets. Thus trainees with strong visual analysis abilities are likely to score well on the 6- and 8-second measures which allow enough time to detect targets. In particular, the 8-second measure presenting a slight increase in the variance in comparison to the 6-second measure suggests that the more time available to detect targets is associated with higher performance on the subjects. ScreenX's reaction time and false alarm measures were not predictive of performance on the Core Content course.

5.2.2. SAMAE: Scanning and the Core Content course

The Scanning exercise provided two detection scores (4-second and 15-second), and a reaction time and false alarm measure. The results for the Scanning exercise revealed a significant relationship between the 4-second measure and five of the subjects: Aviation Legislation; Avionics; ICAO Organisation, Procedures and Documents; Principles of Flight; and Meteorology. Trainees who scored a high percentage of hits within the first four seconds of a target's appearance also obtained higher marks in these subjects. Thus, the ability to make quick and efficient detections is important. Scanning's 4-second detection measure contributed from 10 to 26% of the variance on these subjects, suggesting that it is a weak to moderate predictor of trainee performance on the Core Content course.

Scanning's 15-second detection measure assessed the percentage of hits over a fifteen second period for which a target appeared on the display. It therefore allowed more time for detection than the exercise's 4-second measure or ScreenX's three detection measures. Scanning's 15-second measure allows for participants to adopt a thorough and persevering approach, especially if they do not detect a target within the first few seconds (Donald, 1998b). Despite the extra time allowed, the 15-second measure was only related to one of the Core Content course's subjects – Aviation Legislation. This was a strong positive correlation, and contributed to 24% of the variance. The relationship between visual analysis and Aviation Legislation was surprising. However, it may be due to the nature of the legislation subject and the way it is assessed. Rules of air (legislation) forms a large component of the course and trainees are required to analyse the situation, apply their knowledge to scenarios and identify consequences associated with such rules for a range of ATC related factors. Outstanding performance on this course therefore depends on the ability to analyse scenarios and apply knowledge.

Scanning's reaction time measure was significantly and negatively related to the same five Core Content subjects as the 4-second detection measure: Avionics; Aviation Legislation;

ICAO Organisation, Procedures and Documents; Principles of Flight; and Meteorology. Longer reaction times were associated with lower marks in each of the subjects. This suggests that trainees' ability to analyse situations quickly, visualise situations efficiently, and to process information and react quickly, contribute to performance on these subjects. This is consistent with the role of controllers who are required to respond quickly and accurately to situations. Scanning's reaction time explained from 13 to 24% of the variance on these subjects.

The results revealed a significant negative relationship between Scanning's false alarm measure and the Aeronautical Messaging Practical subject, where a high number of false alarms were associated with lower levels of performance. The false alarm measure assesses operators' ability to identify and discriminate between elements of a target and a standard picture (Donald, 1998). This is in line with the requirement that trainees recognise key features and identify inconsistencies in messaging and read-backs in messaging. However, the false alarm measure only accounted for 10% of the variance, indicating that other factors are important in performance on this subject.

Having considered the significant relationships and strength of contribution for the Scanning exercise, it appears that the 4-second detection score is a more useful measure than the 15-second measure as it is related to performance on five of the Core Content subjects as opposed to one subject. Although contributing in a weak to moderate manner, it is evident that the ability to detect targets quickly contributes to performance. By contrast, the 15-second measure predicted only one subject on this course, but was a fairly strong predictor and explained a larger percentage of variance. The results for Scanning's reaction time measure were similar to the 4-second detection measure, as it predicted the same five subjects in a weak to moderate manner. Scanning's false alarm measure was possibly the least useful score as it only predicted performance on one subject in a weak manner.

5.2.3. SAMAE: Division of Attention and the Core Content course

The nature of the items in SAMAE's Division of Attention exercise differed from the Scanning and ScreenX exercises. While the latter required comparison of one complex graphic object with a standard object, the Division of Attention exercise requires respondents to monitor a number of moving objects simultaneously and to detect various types of changes in them (Donald, 1998). The Division of Attention exercise included one detection measure (over four seconds), a reaction time and false alarm measure.

Results for the Division of Attention exercise revealed a positive relationship between the detection measure and one subject on the Core Content course – Meteorology. Higher numbers of detections were associated with higher performance in this subject. The detection score explained 23% of the variance on this subject. This is possibly explained by the fact that the Division of Attention exercise requires respondents to constantly search for and detect changes in a number of moving objects (Donald, 1998b). The Meteorology subject requires trainees to detect changes in meteorological conditions within given scenarios and how they impact on ATC related factors. An example of this is monitoring changing weather conditions and how they affect management of the airspace, taking into consideration the type of aircraft and its performance capabilities within such conditions.

Division of Attention's reaction time predicted performance on two subjects on the Core Content course – Meteorology and Avionics. Similarly, to the detection measure for Division of Attention, this exercise's reaction time was also significantly related to Meteorology. However, it only explained 12% of the variance for this subject. The relationship was negative, indicating that longer reaction times were associated with lower performance on Meteorology. For Avionics, the relationship was also negative and 10% of the variance on performance for this course was explained. This suggests that the ability to monitor and detect changes in dynamic situations contributes to performance on these subjects. No significant relationships were found for false alarms on the Division of Attention exercise and Core Content course subjects.

In summary, the various measures on the Division of Attention exercise are related to performance on only two subjects for the Core Content course – Meteorology and Avionics. It is a stronger predictor for Meteorology than for Avionics. The detection measure is the strongest predictor for Meteorology for this exercise, while the reaction time measure is the only predictor for Avionics. The false alarm measure for Division of Attention was not related to any subjects on the Core Content course.

Taken together, the three visual analysis exercises are related to the overall average for the Core Content course and ten of the fifteen subjects: ATC Theory and Procedures Section B; Aircraft Identification and Performance; Principles of flight; Instruments and Approach Procedures and Area Navigation; ATM/CNS; Meteorology; Aviation Legislation; ICAO Organisation, Procedures and Documents; Avionics; and Aeronautical Messaging Practical. ScreenX seems to have the greatest utility as it is related to performance on seven subjects for this course and the overall course average, while Scanning is related to six subjects and Division of Attention is related to two subjects.

The results of the current study are consistent with previous studies where visual analysis scores have been predictive of performance within CCTV and X-ray screening in aviation and radiology environments (Andrew, Landgrebe & Donald, 2003; Department of Transport, 2003; Donald, 2011; Donald 1998). More specifically, these findings are in line with a previous study where visual analysis has been positively associated with training performance (Donald, 1998b).

5.3. Comparison of Trainees' and Controllers' Visual Analysis Scores

Differences in visual analysis scores for trainees and controllers were examined based on previous research on controllers where differences between novices and experts have been identified (Seamster, Redding, Cannon, Ryder & Purcell, 1993). Significant differences between the sub-samples were found for certain measures on all three visual analysis exercises (i.e. ScreenX and Scanning's 4-second detection measures; Scanning's 15-second detection measure; Division of Attention's detection measure; and false alarms on Division of Attention).

Controllers scored significantly better than local trainees on ScreenX. International trainees were excluded from the ScreenX analyses due to small sample size, so conclusions cannot be drawn about how their ScreenX scores compared with local trainees or controllers. International trainees consistently scored the lowest on SAMAE. Although the scores of local trainees and controllers were not statistically different for SAMAE, these sub-samples both differed significantly from international trainees on Scanning's 4- and 15-second detection measures, as well as Division of Attention's detection and false alarm measures.

These findings suggest tentatively that there are differences in the abilities of trainees and controllers in terms of their ability to visually analyse situations in a very short period of time. If this is the case, visual analysis ability could possibly be developed with experience in occupations that require high levels of visual analysis. However, the samples in this study were small and the different trends for local and international trainees indicate that further research is needed before conclusions can be drawn.

5.4. Contextualisation of Results

Although the visual analysis exercise scores were related to both practical and theoretical aspects of training, most of the results presented a relationship to the latter given that the Core Content course is largely theoretical based. This does present some interesting findings regarding the relevance of visual analysis; given that performance has typically been examined from a practical approach according detection rates on-the-job (Andrew et al., 2003; Donald, F. 2011; Donald 1998b, Department of Transport, 2003).

The findings of the current study demonstrate the relevance of visual analysis to trainee performance on the Core Content course. However, considering that visual analysis explains 9 to 26% of the variance in trainee performance on the course, this indicates that trainee performance draws on analytical abilities that go beyond those required of visual analysis.

Cognitive ability has been determined as one of the most important predictors of performance during training. The extensive use of cognitive ability tests in comparison to other selection tests in training performance emphasises its importance (Gottfredzon, 2002). Furthermore, cognitive ability has been identified as a positive predictor of performance in both theoretical and practical elements within ATC training (Conzelman & Keye, 2014). Having identified the number of cognitive functions required for controller performance on-the-job (as demonstrated in the theoretical background of this paper, Chapter 2), it is reasonable to believe that visual analysis provides only one of the inputs to the many cognitive processes involved in training performance. The importance of cognitive ability is revealed when considering the assessment on the Core Content course from an information processing perspective (Wickenset al., 1997).

The importance of long-term memory is clearly evident in the learning process, where knowledge and schemas (e.g. ATC procedures, aircraft capability, and aviation legislation) are developed throughout the duration of the course. However, the assessment of the course requires further cognitive functioning as trainees are expected to apply their knowledge (stored in long-term memory) to a given scenario. This indicates the importance of selective attention, where specific details of the scenario must be attended to in order to inform the trainee's understanding of the given situation. Working memory forms an essential component as it enables trainees to retain certain details of the scenario (e.g. spatial representation of the airspace, location of aircraft, or weather conditions as detailed in the scenario) which may then be interpreted on the basis of knowledge or schemas stored in long term memory to assist in comprehension of the situation. This understanding evidently informs the situation awareness of the trainee to the given scenario, further enabling them to predict and, thereby, engage in subsequent decision making in order to respond appropriately.

Although cognitive ability is regarded as a prerequisite to occupations such as ATC, which are in fact cognitively demanding, it has however, been noted that performance during training cannot be predicted by such abilities alone (Viswesvaran & Ones, 2002). A number of factors have been identified as predictive of training performance beyond cognitive aspects such as: personality traits; biographical factors; general cognitive ability; motivational factors; self-efficacy; effort regulation; approaches to learning; and psychosocial contextual influences (Gottfredzon, 2002; Richardson, Abraham & Bond, 2012).

Personality traits such as those identified in the Big Five personality factors (i.e. extraversion, agreeableness, conscientiousness, neuroticism and openness to experience), have been found to be predictive of performance during training in a number of different fields (Busato, Prins, Elshout & Hamaker, 2000; Chamorro-Premuzic & Furnham, 2003; Lievens, Coetsier, De Fruyt & De Maeseneer, 2002; Poropat, 2009). A number of personality factors, some of which extend beyond the Big Five personality factors, have also been identified as predictors of training performance within the context of ATC (King, Retzlaff, Detwiler, Schroeder & Broach, 2003; Nye & Collins, 1991; Schroeder, Broach & Young, 1992).

Individual factors based on biographical data (e.g. age, gender, academic qualifications, experience, socioeconomic status) have also been assessed in training performance (Poropat, 2009) and have been identified as predictors of trainee performance in ATC (Collins, Nye & Manning, 1992; Fox, 2014) In addition, individual ability has been positively associated with training performance (Busato et al., 2000) and specific abilities which closely align to cognitive processes such as; spatial visualisation and reasoning abilities have been predictive of training success in ATC (Ackerman & Kanfer, 1993; Ackermann, Kanfer & Maynard, 1995).

Motivation which has been examined in various forms such as; achievement motivation or as an outcome based on the Self-determination theory (SDT) has been regarded as a determining factor in training performance (Archer, 1994; Busato et al., 2000; Colquitt, LePine & Raymond, 2006; Vansteenkiste, Lens & Deci, 2006). Motivation has been specifically identified as an important factor in trainee performance in ATC (Gollwitzer & Bargh, 1996). Self-efficacy (one's perceived ability) has also been predictive of trainee performance where high self-efficacy has resulted in higher performance (Chemers, Hu & Garcia, 2001; Lent, Brown & Larkin, 1984). In addition, one's approach to learning has been predictive of training performance, such as: self-regulated learning (SRL) and self-directed learning (SDL) (e.g. Pintrich, 2000; Pintrich & De Groot, 1990; Pintrich & Zusho, 2002; Zimmerman, 2002). SRL has significantly predicted performance in ATC training (Kanfer & Ackermann, 1996) and furthermore, been examined along with SDL and self-efficacy as determining factors of ATC trainee performance (Conzelman & Keye, 2014).

There are numerous other factors in the research which have been predictive of performance during training such as: individual thinking styles (Grigorenko & Sternberg, 1995), critical thinking and decision making skills (Brooks & Shepherd, 1990; Shin, 1998), which clearly indicate the complexity of trainee performance. However, beyond addressing such factors, it must be acknowledged that training within ATC extends beyond the individual trainees, to other stakeholders within the training processes, namely trainers and designers. These stakeholders play an important role in determining the skills which are developed and trainees come to possess and thus ultimately determine their performance (Elen & Lowyck, 1998). With this in mind, a number of factors should then be considered, such as: the course material learnt, style of teaching, and support of trainers throughout the training process (Conzelman & Keye, 2014; Williams & Deci, 1996).

Having considered the numerous factors contributing to performance during training; the percentage of variance explained by the visual analysis exercises of 9 to 26% for 10 out of the 15 Core Content subjects appears to be quite substantial. The findings of the current study appear to indicate that visual analysis skills are in fact contributing to the interpretative analysis required of trainees in order to perform in the Core Content course.

The relationship between visual analysis and a range of theoretical subjects on the Core Content course suggest tentatively that a general analytical ability might underpin visual analysis. This general analytical ability would apply to situations that do not necessarily involve visual stimuli, such as the analysis of auditory inputs, patterns of stimuli from various sources or events, and mental models of systems. Based on multiple resource theories of attention (e.g. Wickens, 2002), it is possible that visual analysis relies initially on visual attention resources, but that other cognitive processes are then involved in analysing the visual stimuli.

Visual analysis forms part of the perceptual phase of information processing, and this links it to situation awareness. Situation awareness is a critical competency for controllers (Endsley & Rodgers, 1998). The first level of situation awareness involves perceiving relevant information from the environment (Endsley, 1995). It is assumed that visual analysis is likely to feed into this process. The comprehension of situations (level 2) is based on accurate information, which in turn is related to the ability to make accurate predictions of future events (level 3). All three levels are required for accurate situation awareness, and the results of this study suggest that visual analytical ability is one of the competencies required of ATC trainees. Poor situation awareness; and incomplete and erroneous understanding of situations hamper the projection of future status (Endsley, 1995). As accurate visual analysis is possibly one of the foundations of situation awareness, it is likely to assist in the formation of accurate situation awareness. This is important when considering that situation awareness forms the basis for decision-making (Wickens & Hollands, 2000). Thus, in the safety sensitive environment of ATC, it is essential that sound decisions based on accurate situation awareness be made (Durso & Manning, 2008).

5.5. Limitations of the Study

It is important to note the limitations of this study. A cross-sectional research design was used and this limits the degree to which causal conclusions can be made. This limitation is further emphasised by the fact that the study utilised a correlation research design. Although the results support the argument of there being a relationship between visual analysis and trainee performance, there remains a possibility that the outcome variable (trainee performance) may in fact have caused the predictor variable (i.e. developed visual analysis skills). This is referred to as reverse causation (Stangor, 2011).

The results of the current study indicate a relationship between visual analysis and trainee performance. These findings are to some degree supported by previous research examining visual analysis in other visually intensive occupations. Visual analysis has been identified as a predictor of operator performance in CCTV and X-ray screening in aviation, utilising the same or similar instruments as in the current study (Donald, 1998, Donald, 2011, Department of Transport, 2003). However, given that the current study was the first to examine visual analysis in the context of ATC, there is no means of supporting or refuting these findings. Thus, the ability to generalise these findings to all contexts of ATC is uncertain. Future research is required in order to validate these findings.

The sample size was fairly small. It must, however, be noted that most research within the context of ATC has been based on small sample sizes in studies on qualified controllers (e.g. N= 10 in Stein, 1992; and N=20, Endsley & Rodgers, 1996). When considering these samples, the current study's sample size (25 qualified controllers and 66 trainees – including international trainees) is relatively large.

The sample size reflects the issues associated with obtaining larger samples in real life settings (Stangor, 2011). The context of ATC presented challenges to the researcher given that only a limited number of controllers were on duty at any given time and their ability to participate was largely dependent on the time available to conduct the assessments. Time constraints presented a major challenge to the current study. The time required of controllers to participate in the research had to be carefully managed so as to prevent standard work schedules, shifts and relaxation times from being affected. Given the highly complex and safety sensitive nature of ATC, the goal of the researcher was to ensure that participating in the research did not result in poor controller performance. The limitations of obtaining a larger sample also extended to the number of trainees, where assessment times had to fit in with their training schedules. The sample size was further determined by the amount of trainees who attended each of the courses.

The language used to conduct the current research could have affected the findings. All information and instructions were given in which was not the first language of all participants. However, all participants are required to speak English at a certain level in order to train and work in ATC, and therefore special arrangements were not made for other languages. However, it must be noted that the researcher took care to ensure that all participants understood what was required of them and additional explanations or assistance was provided when necessary.

The applicability of the visual analysis exercises (ScreenX and SAMAE) to the context of ATC could have implications for the ecological validity of the study. This is because the visual analysis exercises required trainees and controllers to observe one display on a computer screen and respond by the use of a computer mouse. This differs from the operational context and training environment in which controllers are expected to perform (e.g. radar and weather displays, FPS and other inputs). However, given the difficulty of conducting research within such a complex environment as ATC; the visual analysis exercises which as an independent measure; provide a viable alternative to overcoming such problems.

The appropriateness of the data used in the current study should be considered. The use of course reports as a measure of trainee performance was appropriate considering that they encompass all the criteria required for trainees to pass the relevant courses as stipulated by the ANSP. In addition to the course reports which were based on theoretical assessments, practical assessments (e.g. simulators) would have been useful. However, this was not possible in the amount of time available for this study.

5.6. Recommendations for Future Research

The first recommendation for future research is aimed at obtaining a larger sample of both trainees and qualified controllers. Increasing the sample of trainees should extend to all the ATC courses trainees are expected to attend prescribed by the ANSP. This would allow future research to examine visual analysis in relation to all ATC courses and thus overall training. Increasing the sample of international trainees would also be beneficial in order to provide a more definitive comparison between the level of visual analysis ability between national and international trainees and the implications of potential differences.

Research in the area of the current study could be further expanded by examining the visual analysis performance requirements of qualified controllers according to different facilities, namely: tower, area and radar control. This may provide interesting findings where a difference in performance is observed. Such research could further be extended to examining whether visual analysis ability is further influenced by the degree of traffic and equipment available within each facility.

A longitudinal study would be useful. This would allow for researchers to examine the visual analysis ability of trainees prior to attending the Core Content course and thereafter as trainees obtain different ratings and level of experience. This may indicate the extent to which visual analysis can be developed or further enhanced throughout the training process. Future research may also direct such findings to establish whether the visual analysis exercises (ScreenX and SAMAE) may be adopted as a selection tool aimed at identifying candidates who possess this ability which could also have positive outcomes related to training performance.

The visual analysis exercises used in the current study have been utilised in previous research assessing vigilance in CCTV surveillance operators (Donald, F. 2011). Given that vigilance has been identified as an important requirement within ATC (Parasuraman et al., 2009; Warm et al., 2008; Wickens et al., 1997), the current research should be extended to examining vigilance based on SAMAE both for trainees and qualified controllers.

Conducting a job analysis of controller operations would be beneficial to profile the competencies and work factors required of controllers within the specific ANSP concerned. This would allow researchers to determine the applicability of these specific visual analysis exercises (ScreenX and SAMAE) to ATC and furthermore to establish the degree to which these instruments evaluate the capacity of controllers to effectively perform on-the-job.

The current study utilised visual analysis scores based on single instruments. However, future research may look at examining visual analysis performance based on a combination of scores across two or more of the visual analysis exercises where a composite measure of ability could be recorded. For instance, an overall measure of efficiency could be achieved by taking accuracy of detection in conjunction with false alarms into account, where high accuracy and a low number of false alarms would reflect high levels of efficiency. Measures from signal detection theory, such as sensitivity (d prime or a) (Green & Swets, 1966) could be used for this. Given that a composite measure has been proven to provide more predictive utility in previous research, this may be useful for future research aiming to replicate the current study (Donald, 1998b).

5.7. Implications for ATC

The findings of the current study have indicated the association between visual analysis and performance within the context of ATC. Previous research has identified a number of cognitive factors required on-the-job (Eurocontrol, 1996; Wickens et al., 1997) and has sought to improve controller performance by examining visual scanning and eye-tracking (Ellis, 2006; Stein, 1989; van Meeuwen, 2015). However, the current study suggests that visual analysis is an area worthy of consideration. Given that the visual analysis exercise instruments are associated with trainee performance on a number of the Core Content course subjects, visual analysis may be an underlying ability enabling individuals to perform within the ATC environment. Based on these findings, the use of visual analysis instruments may serve as an additional selection tool to identify individuals or potential trainees who would be likely to succeed in training. On the other hand, if future research indicates that visual analysis ability can be developed in individuals, a focus on developing this ability could serve as a valuable intervention within the current training process.

CHAPTER 6: CONCLUSION

This study examined the relationship between visual analysis and performance during the first training course attended by aspiring controllers. A series of correlation and regression analyses were run between the visual analysis exercise scores (ScreenX and SAMAE – Scanning and Division of Attention) and trainee performance based on Core Content course reports. The results showed that the visual analysis scores were related to performance on ten of the fifteen subjects covered during the Core Content course, as well as the overall course average. Secondary analyses found significant differences in the visual analysis abilities of trainees and qualified controllers.

The findings of this research contribute to a greater understanding of trainee performance within ATC. Having identified visual analysis as being related to trainee performance, this research suggests that visual analysis should be regarded as an additional input to the many cognitive functions which are required in ATC. Furthermore, based on these findings it is suggested that visual analysis be considered in the selection of ATC trainees, which may serve to enhance training success rates and ultimately, qualified controller performance. There are nevertheless a number of other factors that extend beyond visual analysis and cognitive processing which impact on trainee performance. This research therefore suggests that visual analysis should form part of a systemised approach to managing trainee performance within ATC.

This research differs from previous research within ATC based on visual scanning (e.g. Stein, 1992, Ellis, 2006) which have primarily aimed to address visual related errors in ATC and subsequently how controller performance may be improved. Instead, the findings of this research suggest that controller performance may be further explained by visual analysis which may, in turn be underpinned by a more general underlying analytical ability. Secondary analyses tentatively suggest that qualified controllers show a higher level of visual analysis ability than trainees. Therefore, future research should examine the contribution of visual analysis abilities to controller performance on-the-job.

This research has also expanded the area of visual analysis which has predominantly been studied within CCTV, X-ray screening and radiology environments. The relevance of visual analysis to ATC has strengthened the extent to which visual analysis may be generalised to visually demanding occupations and complex environments such as ATC. The findings further demonstrate the utility of ScreenX and SAMAE within these occupations.

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Appendices

Appendix A: Clearance Certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

HUMAN RESEARCH ETHICS COMMITTEE (SCHOOL OF HUMAN & COMMUNITY DEVELOPMENT

CLEARANCE CERTIFICATE	PROTOCOL NUMBER: MORG/14/005 IH
PROJECT TITLE:	Visual analysis in air traffic controllers.
INVESTIGATORS	Gould Megan
DEPARTMENT	Psychology
DATE CONSIDERED	05/05/13
DECISION OF COMMITTEE*	Approved

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

DATE: 19 June 2014

CHAIRPERSON ____________
(Professor M. Nduna)

cc Supervisor: Dr. F Donald
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 2016

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix B: Participant Letter

Psychology

School of Human & Community Development

University of the Witwatersrand

Private Bag 3, WITS, 2050

Tel: (011) 717 4500 Fax: (011) 717 4559

Dear Air Traffic Controller

My name is Megan Gould, and I am a Masters student at the University of the Witwatersrand. I would like to invite you to participate in research that my supervisor Dr Fiona Donald and I are conducting on air traffic controllers. Dr Fiona Donald is a lecturer at the University of Witwatersrand. As you know, air traffic controllers perform a challenging and complex job, and we are examining how visual analysis skills contribute to success in this role.

Participating in the research involves completing three visual analysis exercises. This will take about 2 hours and will be arranged at a time that suits you. Participation is voluntary, and you will not be advantaged or disadvantaged in any way for choosing to participate or not to participate in the study. You can withdraw at any time during the exercises if you wish to. Your individual results will remain confidential and will not be given to the ANSP - only group trends will be reported. To evaluate how relevant the visual analysis skills are, we will also need access to your training results and/or annual proficiency test results, and will need your consent for this.

If you are willing to take part in the study and to allow us access to these results, please complete the attached form and give them to us when you complete the exercises.Completion of the form will be considered consent to participate in the study. Please feel free to phone me at 082 226 9015 or email me at megan00g@gmail.com if you have any queries. You may also contact my supervisor Dr Fiona Donald at 011 717-4507 or e-mail at Fiona.Donald@wits.ac.za.

Thank you for taking the time to consider taking part in this study. If you are interested, I will send you a summary of the results of the study when it is finished.

Yours sincerely

Megan Gould

Masters Student

School of Human and Community Development

University of the Witwatersrand

Phone: 082 226 9015

Dr Fiona Donald

Senior lecturer

School of Human and Community Development

University of the Witwatersrand

Phone: +27 (11) 717 4507

Appendix C: Consent Form

I ____ consent to participate in the study by Megan Gould on visual analysis skills in air traffic controllers.

I understand that:

- Participation is voluntary
- No information that may identify me will be included in the research reports, and my responses will remain confidential
- Individual results will not be provided to management.
- I will not be advantaged or disadvantaged in any way by participating in the study
- I may withdraw from the study at any stage during the visual analysis exercises if I wish to
- I understand that data will be stored securely on completion of the study.
-

Please circle the phrase that applies:

- I **do / do not** give consent to complete the SAMAE exercise
- I **do / do not** give consent to complete the ScreenX exercise
- I **do / do not** give consent to the researchers to access my training results and/or annual Proficiency test results for the purpose of this research.

Name: _______________________________ Signed: ___________________

Phone number (w): _____________________ Cell: _____________________

Date:___________

Appendix D: Demographic Questionnaire

Visual Analysis Research

University of the Witwatersrand

Please could you complete this form. The information will be used for research purposes only and will not be given to any other party.

Name	
Age	
Nationality	
First language	
Position/Grade	
Gender	
Highest education level	

Thank you.