Examining the Influence of Error Climate on Aviation Maintenance Performance

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Abstract

Errors and violations are an everyday occurrence but in safety focused industries, such as aviation maintenance, the implications can be grave. To address the urgent need to provide empirical evidence of precursors of unsafe acts, the present study examined the role of error climate in aviation maintenance performance. Survey data were collected from 189 Technical Trade personnel in the Royal New Zealand Air Force.

Error climate is a relatively new construct that refers to employees shared perceptions of organisational practices regarding errors and is divided into two types, error management climate (EMC) and error aversion climate (EAC). An EMC acknowledges the inevitability of error and has practices that deal effectively with error. An error aversion climate (EAC) conversely, denies error and is characterised by a fear of error and a reluctance to discuss error.

The current study revealed two facets of EAC, these were error strain and covering up errors. EAC and EMC were negatively correlated. Higher levels of EMC were associated with better supervision and psychological health and lower levels of EAC, violations and errors. Higher levels of EAC were associated with the opposite pattern of findings, more violations and errors, worse psychological health, poorer supervision and lower levels of EMC. Two types of violations were found, situational violations which were related to getting the job done in the face of situational constraints and routine violations which reflected rule defiance. Significant predictors of situational violations were routine violations, covering up errors, stress, position (seniority) and general psychological health while significant predictors of routine violations were situational violations and fatigue. Significant predictors of errors were routine violations and position. The effect of error climate on errors was partially mediated by violations. This result is consistent with that of safety climate which is a well established predictor of unsafe acts. Unexpectedly, psychological health did not act as a mediator. These findings suggest that error climate is an important organisational factor in safety and aviation maintenance performance that warrants further examination.

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Glossary

Technical Trades

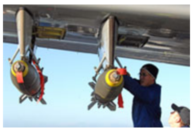
AEROMWKR

Aeronautical Metal Worker: Responsible for the manufacture and repair of a variety of equipment, using various metals and alloys.

ARMMECH

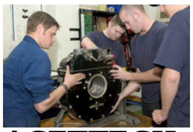
Armament Mechanic: Completed Primary Trade Training and currently undertaking on the job training, but yet to complete Advanced Trade Training to become an Armament Technician.

ARMTECH



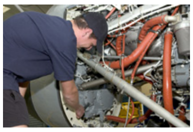
Armament Technician: Responsible for maintaining weapons systems, small arms, explosives demolition, countermeasures and guided missiles for our fleet of aircraft. As well as loading and arming aircraft weapons systems for operational tasks, ARMTECHs perform ground handling and aeronautical maintenance duties.

ACFTMECH



Aircraft Mechanic: Completed Primary Trade Training and currently undertaking on the job training, but yet to complete Advanced Trade Training to become an Aircraft Technician.

ACFTTECH



Aircraft Technician: Responsible for maintaining all aircraft mechanical systems used on RNZAF aircraft including: aircraft structures, flight controls, engines, propellers, helicopter rotors, hydraulics, pneumatics, landing gear and fuel.

AVMECH

Avionics Mechanic: Completed Primary Trade Training and currently undertaking on the job training, but yet to complete Advanced Trade Training to become an Avionics Technician.

AVTECH

Avionics Technician: Responsible for all aircraft electronic and electrical systems and components, including radars, radios, navigation equipment, flight instruments, infra red technology, Night Vision Goggles (NVGs) and electrical generation.

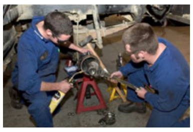
COMPMECH

Composites Mechanic: Completed Primary Trade Training and currently undertaking on the job training, but yet to complete Advanced Trade Training to become an Composites Technician.

COMPTECH

Composites Technician: Responsible for the manufacture and repair of aircraft and aircraft support equipment, and composite and metal-bonded components

GSEMECH



Ground Support Equipment Mechanic: Completed Primary Trade Training and currently undertaking on the job training, but yet to complete Advanced Trade Training to become an Ground Support Equipment Technician.

GSETECH

Ground Support Equipment Technician: Responsible for maintaining the ground–based mechanical equipment required to support RNZAF aircraft operations e.g. motor vehicles, refuelling equipment, hydraulic rigs, hoists and other small engine equipment.

Machinist

Machinist: Responsible for the manufacture and repair of aeronautical and non-aeronautical equipment, using a range of complex and technically advanced machines and tools.

SSMECH

Safety and Surface Mechanic: Completed Primary Trade Training and currently undertaking on the job training, but yet to complete Advanced Trade Training to become a Safety and Surface Technician.

SSTECH

Safety and Surface Technician: Responsible for servicing, maintaining and repairing the RNZAF's aeronautical safety and survival equipment (e.g. parachutes, aircrew protective equipment, life rafts) as well as applying, maintaining and repairing the painted surfaces of aircraft and components.

STT: **Small Technical Trades:** Normally includes Composites, Aeronautical Metal Workers, Ground Support Equipment Technicians and Machinists, but for the purposes of this study Safety and Surface Technicians and Armament Technicians are also included as Small Technical Trades.

Pictures and role descriptions downloaded from http://www.stepup.dixs.mil.nz

Roles, Abbreviations and Descriptions:

AC	Aircraftsman
Chain of Command	Hierarchical reporting structure
CPL	Corporal
DASH	Directorate of Air Force Safety and Health
FEGs	Force Element Groups (FEGs) - the four operational squadrons (units) within the RNZAF – 3 Squadron (Helicopters), 5 Squadron (Maritime), 6 Squadron (Naval Support Helicopters) and 40 Squadron (Transport).
JNCO	Junior Non Commissioned Officer – Corporal
LAC	Leading Aircraftsman
LOSA	Line Operations Safety Audit: The review by expert observers of crew behaviours and situational factors on normal flights.
MFCs	Maintenance Flight Commanders
MSS	Maintenance Support Squadron
NCO	Non Commissioned Officer, includes ranks from Corporal to Warrant Officer.
NZDF	New Zealand Defence Force
Re-enlist	Re-join a military organisation
RNZAF	Royal New Zealand Air Force
SGT	Sergeant
SNCO	Senior Non Commissioned Officer – Sergeant, Flight Sergeant or Warrant Officer. The only SNCOs involved in this study were Sergeants.
Squadron	Unit or division of an Air Force
Tasking	Assigned job or task, usually refers to a flight
Wing	A Wing is a large division of an Air Force and is comprised of Squadrons.

Chapter One: Introduction

Aviation Maintenance errors have devastating and costly implications. Of significant concern in both military and civil aviation is evidence that aviation maintenance errors are increasing (Fogarty, 2004; Hobbs & Williamson, 2003). Efficiencies that achieve safety requirements are urgently being sought however empirical research in this area is sparse. Studies conducted in the Australian Defence Force (ADF) have demonstrated that a substantial proportion of aviation maintenance errors can be explained by the interaction of organisational and individual factors (Fogarty, 2004; 2005). This research suggests that errors are produced when individual psychological health has been compromised by organisational safety climate factors. One organisational factor associated with safety climate, not explored in the ADF research, is that of error climate. Error climate refers to shared perceptions of organisational practices regarding errors. Error climate has been linked to organisational performance in research by Van Dyck et al. (2005). These researchers demonstrated that organisational performance improved in line with a specific type of error climate, referred to as error management climate (EMC), which has at its heart the idea that errors are common, inevitable and informative. Van Dyck et al. (2005) did not research organisations in the aviation industry but highlighted the aviation industry for the significant progress that it had made in implementing error management principles in general. The aviation industry therefore seems to be a suitable place in which to explore the relationship between error climate and performance.

This research project will examine the role of error climate in aviation maintenance performance. It may also result in suggestions for reducing aviation maintenance error and improving efficiency in the maintenance environment. The specific aims of this research project are to assess the error climate of the technical trades in the Royal New Zealand Air Force (RNZAF) and determine whether error climate is an important organisational factor influencing aviation maintenance errors and violations. This research project seeks to demonstrate the links between error climate, supervision, individual psychological health, and self reported aviation maintenance errors and violations.

This thesis has been organised into six chapters. Chapter One will review the literature on errors and violations. Chapter Two explains the two main approaches to error: error prevention and error management. Chapter Three describes the evolution of the theory underpinning error climate and addresses the current study. Chapter Four describes the method utilised in this thesis including the experimental design, measures and procedure. The results are presented in Chapter Five and discussed with reference to previous research in Chapter Six. The thesis concludes with the final statements at the end of Chapter Six.

Errors

Defining Errors

> *"Errors are the failure of planned actions to achieve their desired goal, where this occurs without some unforeseeable or chance intervention".*
>
> (Reason & Hobbs, 2003, p39)

Reason and Hobbs (2003) emphasise that errors are failures of voluntary or controllable actions rather than failures due to luck or misfortune. A second definition is also provided as it highlights the unintentional nature of error.

> *"Errors are unintended deviations from plans, goals or adequate feedback processing as well as an incorrect action that results from lack of knowledge."*
>
> (Van Dyck et al., 2005, p. 1229)

Errors are therefore the accidental result of voluntary or controllable actions, or plans that fail despite the best of intentions.

Types of Error

There are now many taxonomies of error, however the three basic types of error identified by Reason (1990) in his seminal book on human error suffice for this research project. They are slips, lapses and mistakes. Slips and lapses involve erroneous actions while mistakes are errors of planning or decision making (Norman, 1988; Reason, 1990).

Slips: Slips are errors of inattention that occur every day particularly in skilled behaviour which is performed automatically without conscious thought (Norman, 1988). Examples include: phoning home when you meant to call for a taxi, throwing the letter rather than the envelope in the rubbish bin, writing last year's date on a form and accidentally completing a task in accordance with an old rather than a new procedure. The errors of skilled or qualified workers are often slips, as many of their actions are performed automatically. Slips are easily detected through observation and monitoring, and generally have minor ramifications (Norman, 1988).

Lapse: A lapse is a memory related error that occurs either at the time of committing something to memory, during storage or at the point of retrieval (Reason & Hobbs, 2003). Examples include: forgetting an appointment, losing your place on a job after being interrupted, failing to recall a password or code, forgetting a key instruction emphasised at shift turnover and failing to recall whether you turned off the iron before you left home. Some of the more common maintenance errors (e.g. forgetting to remove a tool from an aircraft after finishing a job) are lapses (Hobbs, 2004).

Mistakes: Mistakes are faulty plans or decisions rather than failed actions and often involve incorrect assumptions, the application of bad rules (habits) or incorrect solutions to novel problems (Reason, 1990). Examples include: planning a route through the city that involves driving the wrong way down a one way street, throwing water on an oil fire, not realising the need to check the weather or tides before going sailing and loudly repeating yourself to someone in a language they do not understand as you assumed the lack of response was because they had not heard you. Mistakes are often made by novices or individuals dealing with a novel problem (Reason, 1990). They are generally more difficult to detect and usually have more serious ramifications than the action errors described above (Norman, 1988).

The Distinction between Errors and Violations

The distinction between errors and violations was first highlighted in research by Reason et al. (1988) over twenty years ago. These researchers conducted a study of recreational driver behaviour in order to identify other ways in which human beings contribute to accidents besides error. The analysis revealed a distinct set of driver behaviours that differed from errors and also contributed to accidents. These behaviours (e.g. deliberately speeding) were violations. This distinction has since been replicated in at least four different countries (Stanton & Salmon, 2009) and is acknowledged in industry (e.g. Aviation, Hobbs & Williamson, 2002; Healthcare, Espin, Lingard, Baker & Regehr, 2006). While the distinction between errors and violations is now well established, scholars (e.g. Van Dyck, 2008) are still calling for it to be reflected in the research which is often confounded by the amalgamation of errors and violations. Violations, when they are distinguished, are usually defined as a type of error (e.g. Helmreich, 2000; Dekker 2003; Reason & Hobbs, 2003) even though they are now known to be distinctly different constructs with different antecedents and outcomes (Fogarty & Buikstra, 2008; Van Dyck, 2008).

Violations, unlike errors, are deliberate. Also, errors involve failed actions or plans, while violations often achieve the end goal but do so via a method that is purposely wrong as violations are often calculated shortcuts (e.g. referring to personal notes instead of the publication or manual, missing out a step because it is deemed unnecessary). With violations the action is correct as it is carried out as intended and the goal is usually achieved, but the intention is purposely wrong (Van Dyck, 2008). Violations and errors also tend to have different precursors. While they do have some precursors in common (e.g. organisational factors), violations are usually associated with social, motivational and attitudinal factors while errors are normally linked to cognitive factors (Reason & Hobbs, 2003). Moreover, errors have a direct relationship with adverse consequences (e.g. incidents and accidents) while the relationship between violations and adverse consequences is normally indirect via error (Reason & Hobbs, 2003). As a result of these differences, researchers (e.g. Fogarty & Buikstra, 2008; Van Dyck, 2008) now advocate that errors and violations be studied independently but simultaneously as they are in the current study.

Violations

Defining Violations

Violations were originally defined for accident investigations and were described by Reason (1990) as:

> "*Deliberate – but not necessarily reprehensible – deviations from those practices deemed necessary (by designers, managers and regulatory agencies) to maintain the safe operation of a potentially hazardous system*" (p.195)

Recent definitions are more succinct and no longer mention liability but generally state that violations are:

> *"an intentional deviation from procedures or good practice*"
>
> (Hobbs & Williamson, 2003, p191)

> "*an action that is contrary to a rule*" (Alper & Karsh, 2009, p 740)

Violations include for example: deliberately speeding, contravening the dress code, deliberately taking an unauthorised extended lunch break, jay walking, pulling a 'sickie', sharing passwords, signing off a job before it is finished and not wearing mandatory protective clothing (e.g. goggles, fluorescent vest).

Violations are often referred to in the safety literature as non-compliance, as they represent a deliberate failure or refusal to comply. The positive form, compliance, is more frequently utilised and is defined as:

> "*adherence to safety procedures and carrying out work in a safe manner*"
>
> (Neal, Griffin & Hart, 2000, p101)

Safety behaviour and safety performance are two other terms utilised in relation to violations and compliance in the literature, with safety behaviour scales often employed as a measure of violations (Fogarty, 2005).

Violations are generally defined by intentionality and outcome (e.g. Lawton, 1998; Reason, 1990). They range from unintentional non-malevolent violations to intentional malevolent violations with the former known as erroneous or unintentional violations while the latter are acts of sabotage or terrorism. Neither extreme is the subject of interest in industry studies of violations however, as erroneous violations (e.g. unknowingly speeding) involve unintentional deviations from rules and are therefore classified as errors rather than violations (Lawton, 1998; Reason, 1990); while acts of sabotage or terrorism are usually beyond the scope of industry studies involving violations (Lawton, 1998). The violations in the middle of these two extremes, the intentional non-malevolent violations, are the violations that most industry studies refer to and are concerned with (Figure 1).

Figure 1: Continuum of Violations

Types of intentional non-malevolent violations

Three main types of intentional non-malevolent violations have been identified in the literature: routine violations; situational violations and thrill seeking or optimising violations. Routine violations are the most common and least risky type of violation.

Routine violations:

> "*Frequent and relatively benign shortcuts in familiar situations taken to avoid unnecessary effort, to get the job done quickly, to demonstrate skill, or to circumvent procedures considered to be unnecessarily laborious*"
> (Hobbs & Williamson, 2002, p876)

For example: missing out an unnecessary step in a familiar maintenance task; turning on a cellphone or standing up to get luggage in an aircraft before being authorised; and railway shunters who get on and off the pilot engine while it is moving (Lawton, 1998). These violations are often committed by skilled personnel who believe their skill enables them to determine which steps/rules are unnecessary or how to break them safely to avoid negative consequences. When a rule is routinely violated without negative ramifications it has a tendency to become the norm (e.g. getting up to get luggage before authorised in an aircraft) and is then often committed automatically without conscious thought. Routine violations are common and have been demonstrated in studies involving railway shunters (Lawton, 1998), pilots (Helmreich, 2000) and maintenance personnel (Hobbs & Williamson, 2002).

Situational violations: Situational violations were first identified by Lawton (1998) in a study of rule violations of railway shunters in the United Kingdom. These violations are committed by well intentioned employees trying to get the job done in impractical work situations, such as when there are staff shortages, equipment deficiencies, a flawed work design or inadequate procedures (Lawton, 1998; Reason & Hobbs, 2003). Personnel in these situations do not usually wish to commit a violation but are compelled to do so by the circumstances. For example, Doctors who work longer shifts than safety would allow as there is no one to take over from them; maintenance personnel who improvise a tool as the correct tool is not accessible; personnel who complete a job for which they have not been properly trained as there is no one else available or because they are the most experienced of those available etc. These violations result from management decisions or procedures that are unworkable on the 'shop floor' (Lawton, 1998; Reason & Hobbs, 2003).

Situational violations are often implicitly endorsed as long as targets are achieved but incur reprimands when incidents or accidents result (Lawton, 1998).

Thrill seeking or optimising violations: These violations are not well documented but do exist and are particularly prevalent in practical jokes and initiations (Reason & Hobbs, 2003). Reason and Hobbs (2003) claim these violations are motivated by personal desires which include: showing off, looking cool, having fun or relieving boredom. Examples include: utilising a fire extinguisher in a joke, attempting aerobatic manoeuvres before being authorised and speeding to show off superior car handling to a colleague or friend.

Unsafe Acts

Reason (1990) uses the term unsafe acts to describe errors and violations committed in the presence of a hazard. The different types of errors and violations are displayed in Figure 2.

Active and Latent Errors

In addition to the above classifications of errors and violations Reason (1990) also classifies errors by the immediacy of their consequences or their location within the system rather than the structure of the error itself.

Active errors: Active errors are errors that are almost immediately obvious as they are committed by operators or 'front line' personnel (e.g. pilots, train drivers, mechanics, road workers, paramedics, nurses, factory workers etc) and have direct adverse consequences (Reason, 1990). For example, forgetting to lower the landing gear on approach, administering the wrong medicine to a patient, allowing traffic to pass before the road is clear.

Latent errors: Latent errors are generally associated with personnel removed from front line operations such as managers or designers (Reason, 1990). These errors may inadvertently lead operators to failure but are less obvious as their relationship with adverse consequences is indirect. For example, designing switches that all look the same and placing a frequently utilised switch right next to a rarely needed one. These errors are often related to managerial decisions that lead to ineffective organisational structures and managerial cutbacks that increase employee workloads and decrease access to necessary equipment.

The ways in which organisations manage errors and violations vary widely. Approaches to error are the focus of the next chapter.

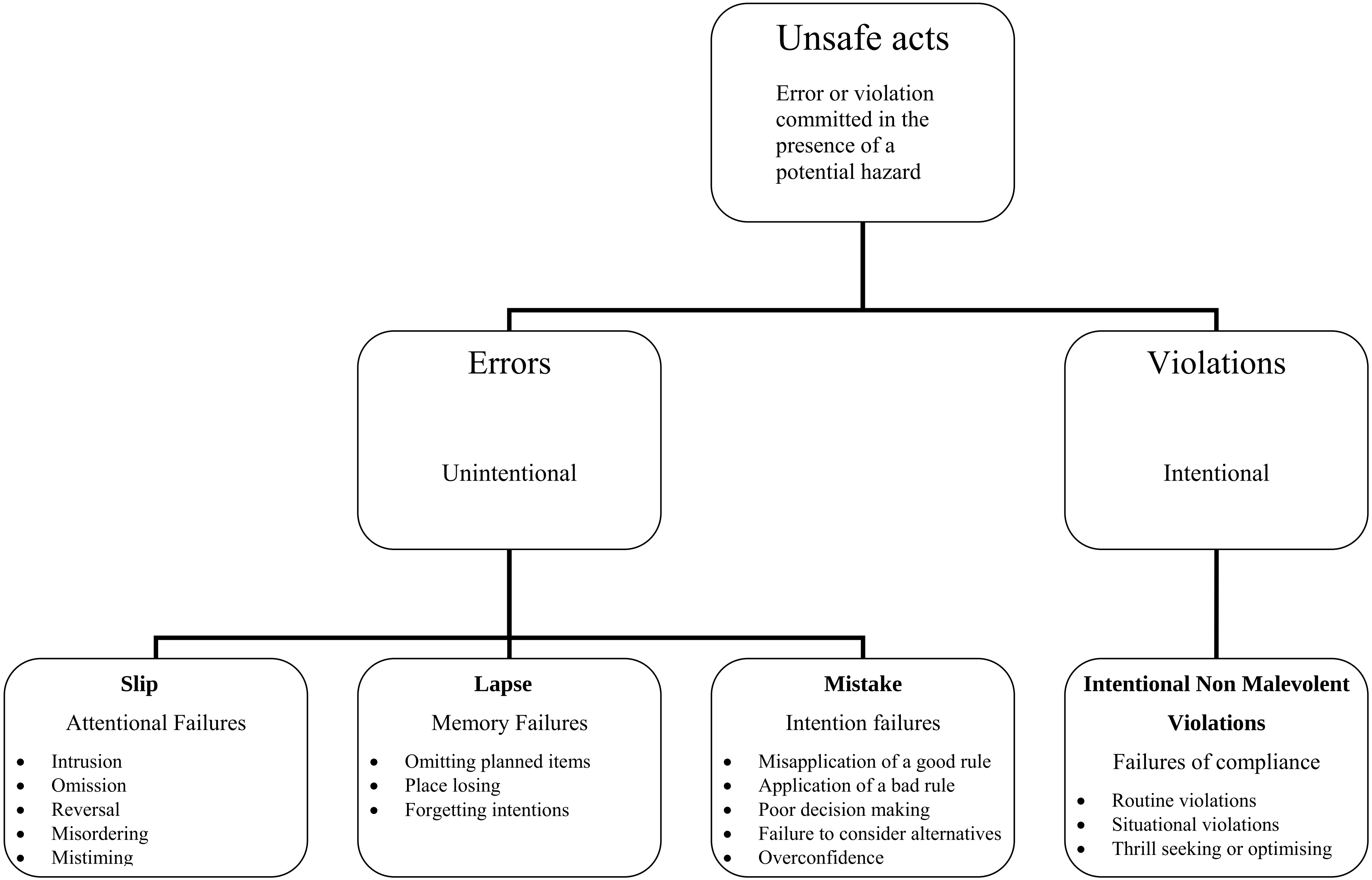


Figure 2: Unsafe Acts (Adapted from Reason, 1990)

Chapter Two: Approaches to Error

Error Consequences

Before the approaches to error can be discussed, a distinction needs to be made between errors, violations and their consequences (Van Dyck, 2008). Error consequences are primarily thought to be negative although there are also positive consequences of error. The negative consequences of error are well known and include for example: cost, time loss, stress, frustration, negative attributions, injuries, incidents and accidents (Van Dyck, 2008). The positive consequences of error are not often emphasised but are also significant and include new information, innovation, future error prevention and most importantly, learning (Van Dyck, 2008).

Errors and error consequences are often confused. For instance, it is common to hear errors described as major or minor. However, the error itself is neither according to Van Dyck (2008), as the same error can have vastly different consequences in different situations. For example, not being able to account for tools or failing to screw a cap on correctly have serious ramifications in aviation maintenance, while the same error at home is not normally cause for concern. Also, an error that results in serious negative consequences is often thought to be worse than the same error when no negative consequences result (e.g. failing to give way when no negative consequences result versus failing to give way when the result is a fatal accident).

This distinction between errors and error consequences is emphasised by researchers (e.g. Reason & Hobbs, 2003; Van Dyck, 2008) for a few key reasons. Firstly, as described above, errors have different consequences in different situations. Secondly, different types of error are associated with different error consequences. For example, lapses were associated more with maintenance quality incidents while slips were linked to worker safety incidents in an Australian maintenance study (Reason & Hobbs, 2003). Also, Line Operations Safety Audits (LOSA) found that 69% of aircrew proficiency errors became consequential (additional error or an undesired aircraft state) while only 2% of violations did (Helmreich, 2000). Understanding the distinction between errors and error consequences allows interventions to be targeted more effectively. For instance, in the example above, slips would be targeted in order to reduce worker safety incidents. Finally, the avoidance of negative error consequences is now advocated to be even more important for reliability than the avoidance of error itself, as it is in the avoidance of negative error consequences, rather than error, that high reliability organisations and superior teams set themselves apart (Edmondson, 1999; Helmreich, 2000; Van Dyck, 2008).

Factors that have been associated with less severe error consequences include communication and correction (Van Dyck, 2008). Communication is important as the more errors are discussed the more likely it is that they will be anticipated and therefore the sooner they will be detected. Detection and diagnosis are both pre-requisites for correction and both are assisted by open communication. For example, a third of the discussions of highly effective flight crews concerned threat and error while poor performing crews dedicated only 5% of their discussions to this topic (Sexton, Thomas & Helmreich, 2000).

Organisations and work units within the same organisations differ in their approaches to managing error and error consequences which impacts on risk exposure, error frequencies and consequences. For example, Edmondson (1999) and Helmreich (2000) both demonstrated that threats, errors and error consequences differed markedly between units within organisations as well as across organisations within the same industry. The different approaches are outlined next, along with evidence for their relationships to error frequencies and consequences.

Approaches to Error

There are two main approaches to error: the traditional error prevention approach and the more contemporary error management approach. The error prevention approach considers errors to be entirely negative and as such is concerned with stopping erroneous action. The aim of this approach is to avoid error and its negative consequences through the control of action (Reason, 1990). The error management approach on the other hand, advocates that errors are common, inevitable and informative. It therefore focuses on the quick detection and the correct handling of error to minimise error consequences (Van Dyck et al., 2005).

According to the error management approach, errors can be framed in either a positive or negative light. How the error is framed has important ramifications for the consequences of error. The error management approach also recognises that errors can have positive as well as negative consequences and therefore aims to reduce negative and promote positive error consequences (Van Dyck et al., 2005).

Error Prevention

Error prevention is the traditional approach that Skinner advocated over fifty years ago and that was largely unchallenged as the dominant approach to error until the late 1980s / early 1990s (Frese & Altmann, 1989). Arguments in support of this approach, which has at is core the avoidance of error, came from the scientific traditions of behaviourism and a brand of humanism which shared an entirely negative view of error (Frese & Altmann, 1989). Skinner represented the behaviourist tradition. He likened errors to punishment and recommended that errors be avoided as like punishment, errors were considered to be demotivating and stressful, and thus detrimental to learning and performance. Skinner's thoughts on punishment are summarised by Frese and Altmann (1989) below:

> "*Punishment does not lead to positive learning. Punishment just leads to a temporary suppression of a certain behaviour; it leads to emotional arousal and it does not tell the learner what he or she should really do (just doing nothing helps to avoid punishment as well)"* (p66).

Other behaviourists also advocated the avoidance of error approach. They argued that errors would lead to incorrect learning. This is a concern that is now commonly held and was expressed by pilots undergoing training that exposed them to error (Naikar & Saunders, 2003). Another argument for the avoidance of error emanated from a brand of humanism which claimed that errors were a source of frustration and anxiety. These arguments combined to present an entirely negative view of error that supported the avoidance of error. This view has been reinforced over the years by researchers (e.g. Bandura, 1986), practitioners, and lay people alike, and still prevails in many organisations.

Many organisations consequently developed the notion that errors were 'bad' and as humans were identified as the source of error, organisations sought to avoid error by controlling the actions of employees or removing them through automation in order to avoid error. Systems and protocols were utilised to achieve this aim and provide evidence of efforts to prevent error. Two examples of an error prevention approach include training conducted in accordance with Bandura's (1986) guided error free learning environment and the bureaucratic or 'zero error' work environment.

The guided error free learning environment was proposed as a method of training that enabled errors to be avoided through the control of action. Error free training follows a series of prescribed steps through which learners are guided to ensure that they do not make errors. Errors that do occur are quickly dealt with by the trainer so that they do not become a source of frustration or confusion for the learner. Error free training is the standard approach in many organisations and has been utilised for a wide variety of training courses. For example, technical flying training is still based on an error prevention approach (Naikar & Saunders, 2003).

The error prevention approach is further represented by 'zero error' work environment. Personnel in high reliability organisations such as healthcare and aviation were historically expected to operate in this way as the 'zero accident' policy was traditionally interpreted as a 'zero error' policy in organisations concerned with safety (Kontogiannis, 1999). The error prevention approach is also frequently associated with bureaucratic, hierarchal, organisations which are characterised by a proliferation of rules, procedures, checks and balances that are designed to control action and eliminate error.

The error prevention approach, although it has a worthy aim, has a number of limitations. Firstly, the bureaucracy associated with this approach can be time consuming and off putting, provoking an inefficient work environment. Another limitation is the assumption that errors will not occur as action is directed by rules that prevent errors. This assumption confuses errors with violations and implies that errors are prohibited (Van Dyck, 2008). Therefore, any errors that do occur are seen as a failure or inability to follow the rules.

Consequently, this approach implicates the individual, discourages discussion of error and ironically, given the behaviourist foundations, encourages punishment (e.g. fines). A further limitation of this assumption is that errors are not anticipated and are therefore frustrating as they are not supposed to occur. Also, as the organisation is not prepared for errors, it may struggle with error detection and handling, resulting in more severe error consequences and greater anxiety about error (Edmondson, 1999; Reason, 1990; Van Dyck et al., 2008).

The error prevention approach frequently confuses errors and error consequences such that individuals may be differentially punished for the same error depending on the consequences. For example, if a safety rule is ignored and no incident results the individual may be given little or no punishment. However, if the same safety rule is ignored and an incident occurs, the individual may be severely punished.

The fundamental flaw of the error prevention approach is the assumption that errors can be eliminated. This assumption is refuted by incident databases that demonstrate that errors occur in all organisations, even high reliability organisations (HROs). Moreover, it is now widely acknowledged that incident databases represent only a fraction of the errors that occur and that many errors are not revealed or are covered up due to the threat of blame and punishment that tends to accompany the error prevention approach (Edmondson, 1999). Prior to the early 1990s, accident causation theories supported the dominance of the error prevention approach as they directed blame and responsibility at the individual operator and suggested that the elimination of error was achievable. It is now acknowledged however, that a complex set of organisational and individual factors contribute to accidents and errors, many of which cannot be easily foreseen or resolved. Furthermore, modern organisations are characterised by complex technologies which Perrow (1984) asserts lead inevitably to error.

The error prevention approach to errors and the resulting blame culture is still evident in the healthcare industry in the United States of America which has been under significant pressure since the turn of this century to reduce its error rates (e.g. Bauer & Mulder, 2007;

Fischer et al., 2004; Hoffman & Mark, 2006; Hughes, Chang & Mark, 2009). The aviation industry in contrast has progressed towards an error management approach and has been hailed as an exemplar in safety due to its excellent safety record (Helmreich, 2000). Consequently, researchers and practitioners are beginning to accept that errors will never be fully eliminated even in High Reliability Organisations and that what is most important is the ability to avoid negative error consequences that result in adverse events.

Error Management

Error management was developed as an alternative to the traditional error prevention approach and has at its heart the idea that errors are common, inevitable and informative. It is therefore a useful approach for the management of, rather than the prevention of, error, and as such is focused on the reduction of negative and the promotion of positive error consequences, rather than the avoidance of error itself. Error management emanated from the field of human-computer interaction in the late 1980s / early 1990s where it was initially applied to system design and training. Error management systems are those that are designed to support exploration as well as the quick detection and effective handling of error. Computer design examples include useful error messages, and help and undo functions which can minimise error consequences and promote learning from error. The error management training method similarly "*involves active exploration as well as explicit encouragement for learners to make and learn from errors*" and is in direct contrast to the guided error free learning environment (Keith & Frese, 2008, p59).

As error management developed decades after error prevention it was based on more modern theories and has cognitive rather than behaviourist foundations. How one thinks about error is central to the error management approach which is described by Reason and Hobbs (2003) as a mindset. The theoretical basis for error management is action theory which, unlike Skinner's behaviourist theories, emphasises the link between intention and behaviour, and describes errors as having a positive informative function.

Action theory suggests that work actions are guided by action-oriented mental models that represent knowledge of work systems (Keith & Frese, 2008). Keith and Frese (2008) used the example of a photocopier and the mental model of its workings, which operator's use to guide their actions. An aviation example might be a mental model of a specific aircraft type, its parts and how they fit together and interact. The better the mental model the more effective the actions. The best way to develop mental models according to this theory is through active involvement, with, for instance, the photocopier or the aircraft rather than through passive reading of instruction manuals (Keith & Frese, 2008). Errors are considered to be a natural by-product of that active interaction. They also fulfil an important role in the development of mental models as they expose underdeveloped areas of the model and prompt individuals to enhance areas that are useful. Action theory therefore advocates that errors are natural and beneficial as opposed to preventable and detrimental.

A major breakthrough for error management was that it highlighted that error could be interpreted in a different, more positive light (e.g. as natural) and it emphasised that errors could have positive as well as negative consequences. A key positive consequence of error identified by Frese and Altmann (1989) is learning. Other positive consequences of error described by Frese and Altmann (1989) include being a source of feedback; indicating effective and ineffective metacognitions, revealing the boundaries of applied metaphors; preventing a skill from being automated before it is mastered; facilitating the development of innovative ideas, and the early experience of errors enables a thorough understanding of basic concepts to be developed before complex problems are encountered, which later facilitates the detection and handling of error.

Learning from error can prevent secondary errors and has been linked to improved performance and organisational effectiveness. As errors are an important source of learning, learning from error may be vital to success. Learning from errors does not occur automatically however, but is dependent on critical factors such as an awareness of error, psychological safety and open discussion and analysis of error (Edmondson, 1999). The error management approach fosters such conditions as it promotes error in a positive light that supports a no blame culture. It also encourages individuals to think about and anticipate errors through the development of skills in planning, monitoring and evaluation. Moreover, error management emphasises learning from error.

Error management has consequently demonstrated learning advantages over the traditional error prevention approach, particularly with regard to complex and novel tasks (Heimbeck, Frese, Sonnentag & Keith, 2003). Learning is also more likely to occur when individuals hold themselves accountable for errors, as they have been found to do in error management, but not error prevention conditions, where individuals tend to blame errors on external causes such as time pressure. Negative emotions (e.g. frustration, stress, anxiety) also have a detrimental impact on learning and are inadvertently promoted by the error prevention approach as errors are not supposed to occur but inevitably do. Error management approaches which emphasise learning from error, on the other hand, develop the self regulatory skills that control negative emotions (Keith and Frese, 2005).

Negative emotions are a key negative consequence of error. As well as being detrimental to learning, these emotions have other negative ramifications. Stress theory asserts that they consume cognitive capacity which could otherwise have been dedicated to the resolution of error or to the task at hand (Hockey, 1996). Operating at reduced cognitive capacity also increases the probability of error. Furthermore, individuals under stress are known to stick to habitual responses which may not be optimal and may lead to additional errors. A second negative consequence of error is that feedback from errors can be demotivating and can lead to negative attributions (e.g. "I can't do it because I am stupid / useless") which may make it difficult to rectify and recover from error (Heimbeck et al., 2003).

The error prevention approach hopes to avoid negative error consequences by attempting to avoid error altogether. The error management approach on the other hand, confronts the negative consequences of error and demonstrates that it is possible to limit and control them. Heimbeck et al. (2003) demonstrated that although participants initially displayed negative emotions to error these emotions dissipated the more participants were encouraged to take a positive approach to error and to accept and learn from error. Also, Edmondson

(1999) found that negative emotions such as fear and anxiety were prevalent in hospital units with an error prevention approach. However, they were not evident in other units within the same hospital that took an error management approach. These latter units described error as a natural but serious occurrence, and as errors were seen as a challenge or a learning opportunity the staff were less anxious about error, more willing to discuss error and detected more errors than those in units that described error as a threat.

The error management approach is effective at reducing negative error consequences as it normalises error and compels individuals to reframe error in a positive light and to work through errors that occur. This process leads to the development of self regulatory skills that reduce the negative emotions usually associated with errors and delays. Furthermore, as error management emphasises the need to think about and anticipate error it supports the development of self regulatory skills related to planning, monitoring and evaluation. This leads to the consideration of multiple plans and aids the quick detection and effective handling of error (Keith & Frese, 2008). These are crucial skills given the possible negative consequences of error (e.g. negative attributions, incidents, accidents).

Keith and Frese (2008) proposed that the skills developed by the error management approach would be useful during periods of organisational change when errors are abundant and it is vital to promote positive (e.g. learning and innovation), and reduce negative consequences of error (e.g. delays, frustration). Errors prominent during transition would be less threatening as they have been reframed in a positive light. The anxiety associated with change would be reduced as individuals would have the skills to control negative emotions (Keith & Frese, 2008). Furthermore, the skills required for considering different ways of working and for reviewing work strategies are enhanced and habitualised by an error management approach which makes the adjustment to a new way of working less challenging.

As the concept of error management and the understanding of error have developed so have the principles at the core of this approach. Reason and Hobbs (2003) now define thirteen principles of error management (Table 1). These are based on research and are representative of the actual situation rather than some desired state. These principles have been developed with the safety environment in mind and consequently have a strong emphasis on the control of negative error consequences while acknowledging that error can lead to continuous improvement

Table 1: Principles of Error Management

Human error (including violations) is both universal and inevitable
Errors are not intrinsically bad
You cannot change the human condition, but you can change the conditions in which humans work
The best people can make the worst mistakes
People cannot easily avoid those actions they did not intend to commit
Errors are consequences rather than causes
Many errors fall into recurrent patterns
Safety significant errors can occur at all levels of the system
Error management is about managing the manageable
Error management is about making good people excellent
There is no one best way
Effective error management aims at continuous reform rather than local fixes
Managing error management is the most challenging and difficult part of the error management process (error containment, error reduction and the management of these activities so they continue to work effectively).

(Reason & Hobbs, 2003, p101)

Error Prevention vs. Error Management

Error management was initially promoted as an alternative to the error prevention approach. However, current recommendations are that a combination of the two is required, with error prevention practices providing the first line of defence, and error management practices the second. While the implication is that the two approaches are now complementary, the preferred philosophy is that of the more contemporary error management approach which takes account of advances in human error research.

The ‘bow tie’ model of error defences displayed in Figure 3, demonstrates the advantages of the dual approach to error defences over that of the traditional approach. With the traditional error prevention approach, all defences were devoted to the prevention of error with no defences dedicated to the detection or handling of error. Consequently, when an error did occur, as they inevitably did, adverse error consequences were likely to result as defences were not established to manage error or mitigate error consequences. Error management defences however, are dedicated to the prevention of adverse error consequences and in combination with error prevention practices, provide a formidable defence against their occurrence. The dual approach is the preferred approach as it is now recognised that the prevention of adverse error consequences is even more important than the prevention of the error itself and is the hallmark of High Reliability Organisations.

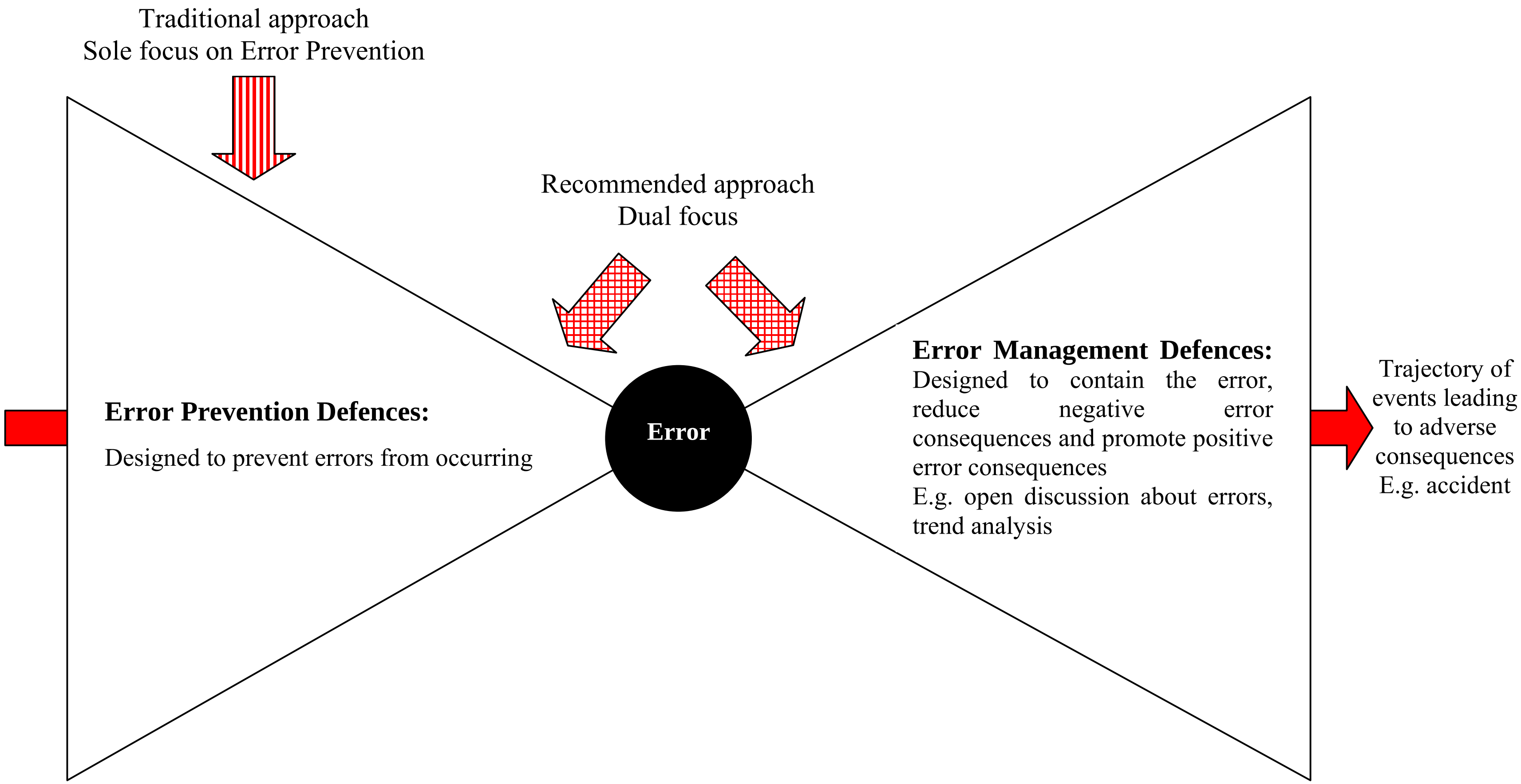


Figure 3: Bow Tie Model of Error Defences (Classic 'Bow Tie" Model adapted from Haden Cave, 2008)

Error Prevention and Error Management in Aviation

The aviation industry traditionally took an error prevention approach. Personnel were expected to operate without error and were guided by an abundance of rules and regulations (Sexton et al., 2000). Historical aviation accidents also indicate that individuals were frequently blamed and punished for error as many aviation accidents were attributed to 'pilot error' or to whichever individual committed the final active error (Wiegmann & Shappell, 2001). As aviation accidents are highly visible and significant, accidents have been intensely studied over a long history. Consequently, the aviation industry has developed skills in analysing error and has strong links to human factors research as it has tried to understand and learn from errors in order to prevent them (Frankel, Leonard & Denham, 2006). By the 1970s, the aviation industry had already implemented human factors research in the form of standardised and simplified rules, as well as human factors training (Frankel et al., 2006). Other human factors initiatives followed and included error reporting systems and the automation of technologies. These efforts were based on the error prevention assumptions that humans were unreliable and that error could be avoided with rules, regulations and automated systems (Naikar & Saunders, 2003).

Traditional perceptions of error in aviation were initially challenged in the early 1990s when organisational factors were implicated in two separate aviation accidents (Haddon-Cave, 2008). These findings forced the aviation industry to re-evaluate its understanding of error and the feasibility of the 'zero error' goal. From this point on there is evidence of the emergence of the error management approach in aviation. For instance, Naikar and Saunders (2003) claim that during the 1990s the aviation industry became increasingly cognisant that error in a complex system such as aviation was inevitable and impossible to eliminate entirely. Furthermore, they claim the industry began to recognise that humans were not only a source of error but also a critical defence against error. Helmreich (2000) also asserts that error management strategies were increasingly utilised in aviation during the 1990s. Furthermore, error management was promoted as an organisational strategy in aviation (Helmreich, 1998). By 2000, the ability to learn from error was emphasised in pilot selection. The management of error was being assessed in Line Operation Safety

Audits (LOSAs). Error management models (e.g. Figure 4) had been developed. Standardised methods of investigating, recording and communicating error information and learning had been adopted. The aviation industry had also been hailed as an exemplar in error management that the United States medical industry was advised to learn from (Helmreich, 2000).

The most compelling evidence that an error management approach was incorporated into aviation in the 1990s however, comes from its formal integration into non technical flying training (i.e. training in cockpit management, teamwork, group processes etc) in the late 1990s, with the introduction of Error Management Crew Resource Management (EMCRM) training.

EMCRM is defined as:

> *Effective utilisation of all available human, informational, and equipment resources toward the goal of safe and efficient flight. Specifically, it is an active process employed by crew members to identify existing and potential threats and to develop, communicate and implement plans and actions to avoid or mitigate perceived threats.* (Helmreich, 2000, p9).

Traditional Crew Resource Management (CRM) training was initiated in the 1980s to provide non-technical flying training to aircrew (Helmreich & Foushee, 1993). This training was based on data and had a positive impact on crew performance. CRM training consequently became an aviation requirement worldwide. However, these early versions of CRM had only a vague goal of enhancing teamwork (Helmreich, 2000). EMCRM on the other hand, is a more directed approach aimed at teaching aircrew countermeasures to error, given that humans have limitations and that error is inevitable, common and informative. Error rather than the individual is framed as the offender while the individual is promoted as a critical defender against error and armed with strategies for that role. EMCRM training also takes the more successful approach of promoting effective behaviours for

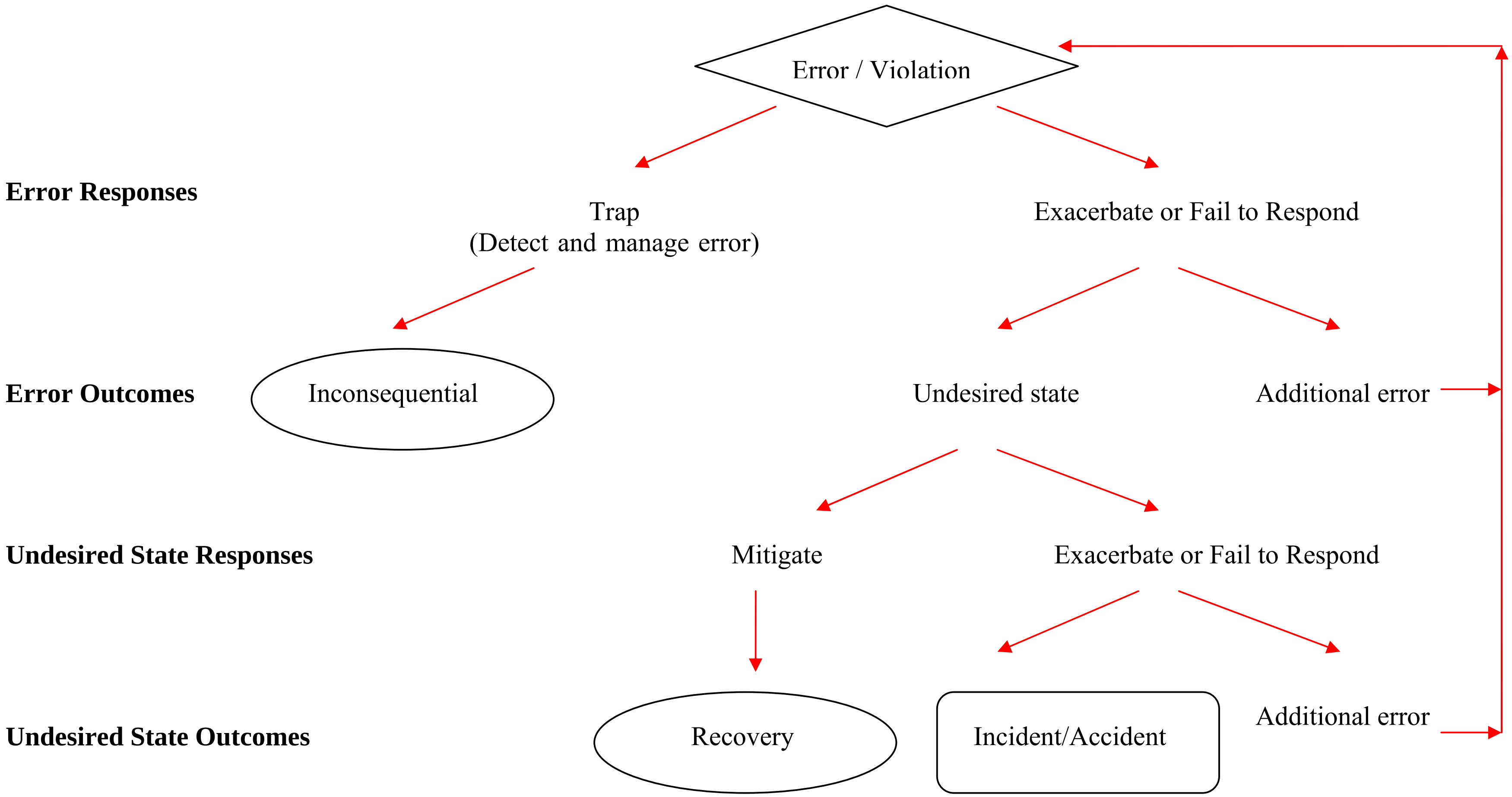


Figure 4: A model of flight crew error management (adapted from Helmreich, 2000)

managing error rather than emphasising ineffective behaviours as was the case in previous versions which were influenced by the error prevention approach (Helmreich, 2000).

Effective error management behaviours form the core of EMCRM. These behaviours were observed to be successful in managing error in Line Operations Safety Audits and include active captain leadership; briefing known threats; asking questions; speaking up; making and reviewing decisions; communicating operational plans clearly; preparing/planning for threats; distributing workload and tasks; and being vigilant through monitoring and challenging (Helmreich, 2000).

The fact that error management had a strong foundation in the aviation industry within a decade of its conceptualisation is testament to aviation's close relationship with human factors research. Two key researchers appear to have been influential in propelling the early adoption of error management in aviation. They are James Reason and Robert Helmreich. James Reason holds a prominent place in aviation as he has applied human factors research specifically to aviation (e.g. Maurino, Reason, Johnston & Lee, 1995). His famous Swiss Cheese model of accident causation is frequently utilised in aviation investigations (e.g. Hadden-Cave, 2008) as the basis for theoretical models (e.g. Fogarty 2004, Helmreich, 2000). Reason dedicated chapters to error management in Reason (1997) and Reason and Hobbs (2003) where error management was defined as having two core components: error reduction and error containment. Error reduction is focused on limiting error while error containment is concerned with limiting the adverse consequences of error. A third component, the management of error reduction and containment was added in Reason and Hobbs (2003). Helmreich was also a strong advocate for the implementation of error management in aviation. As highlighted earlier Helmreich promoted error management in aviation and the introduction of EMCRM. Helmreich (2000) defines error management as:

> "*using all available data to understand the causes of errors and taking appropriate actions, including changing policy, procedures and special training to reduce the incidence of error and to minimise the consequences of those that do occur*" (p1).

Helmreich’s and Reason’s definitions of error management both demonstrate aviation’s dual focus on error prevention and error management practices, as well as its commitment to the error management philosophy of the inevitability of error.

Researchers (e.g. Hadden-Cave, 2008; Helmreich 2000; Naikar & Saunders, 2003) now claim that error management is crucial to flight safety. However, error management while well recognised in flight safety seems to be less established in ground safety. For instance, there are many articles some dating back to the 1990s that discuss error management in relation to the behaviours of aircrew, while this terminology is less prevalent in articles specific to aviation maintenance with the notable exception of Reason and Hobbs (2003). Error management has also been differentially applied across aviation with some areas of aviation advanced in error management while others still operate on the basis of error prevention. For example, non technical flying training is based on error management but technical flying training is still founded on the error prevention approach (Naikar & Saunders, 2003). It appears that mechanics are expected to make mistakes but technicians are not. Errors are expected and accepted in some areas more than others and by some groups such as apprentices but not qualified personnel, more than others. One aim of this study is to explore how relative priorities for error prevention and error management are related to the occurrence of errors and violations. The next chapter considers error climate in organisation.

Chapter Three: Error Climate

"Mistakes are a fact of life. It is the response to the error that counts"[1]

In order to define and explain the importance of error climate and its implications as a construct it is necessary to first describe the climate variables from which it is proposed to be derived. Organisational climate is explained first then safety climate and error climate are discussed. The relationships between these three climate variables are portrayed in Figure 5.

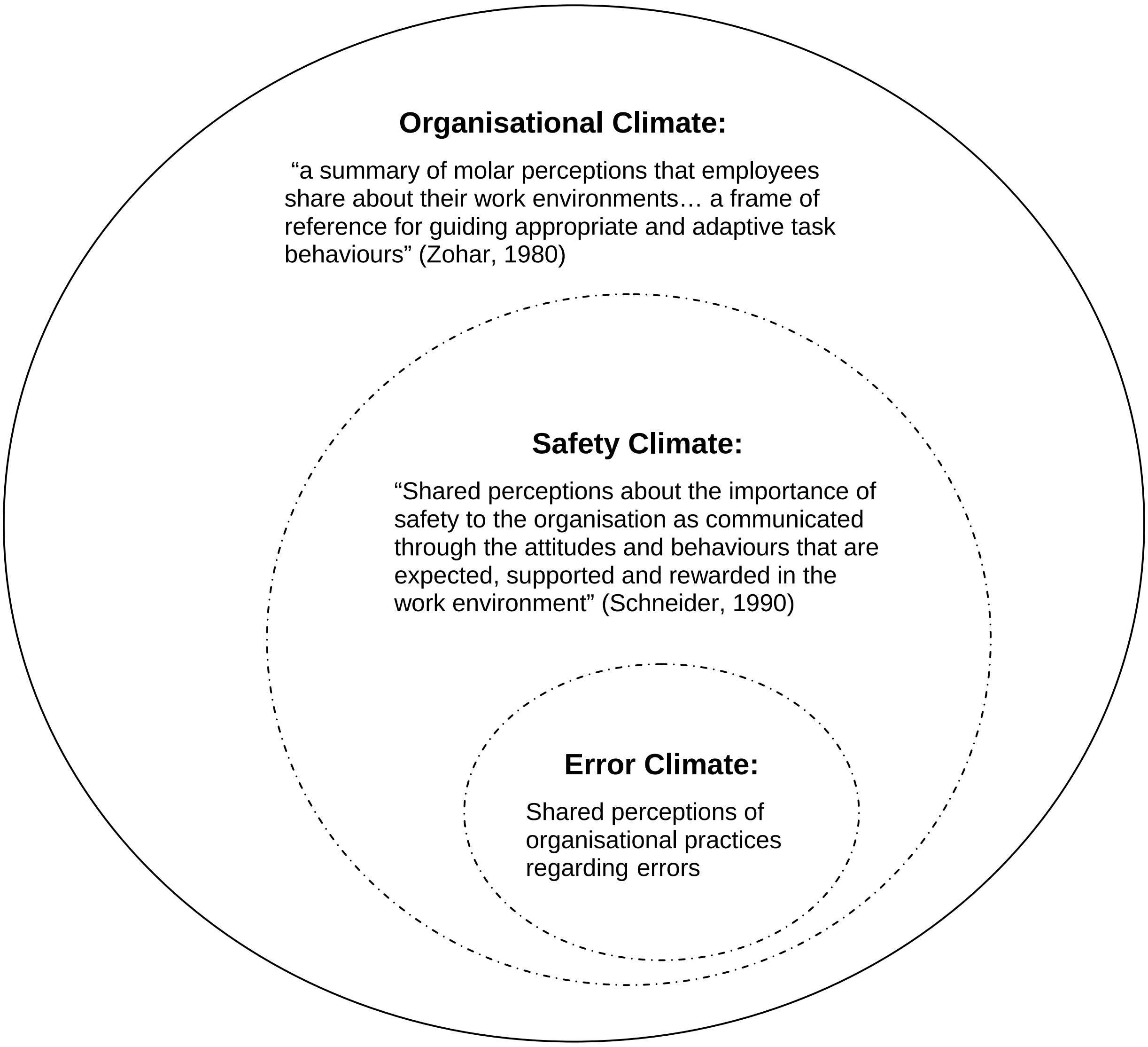


Figure 5: Error climate as a facet of organisational and safety climate

[1] Nikki Giovanni, www.thinkexist.com

Organisational Climate

Organisational climate is an important organisational variable in the study of employee behaviour and job performance and has a long history in psychology dating back as far as 1939. Organisational climate *"concerns the policies, practices and procedures as well as the behaviours that get rewarded, supported, and expected in a work setting and the meaning those imply for the setting's members" (*Schneider, Ehrhart & Macey, 2011. p373).

Although organisational climate has been well studied over the years, comprehension of this concept was complicated by the introduction of the related concept of organisational culture in the 1980s (Denison, 1996; Witte & van Muijen, 1999). Whilst the two concepts were initially distinct they became confused and are often used interchangeably (e.g. Öz, Özkan & Lajunen, 2010) despite frequent clarifications of the distinction in more recent years (e.g. Denison, 1996; Guldenmund, 2000; Schneider et al., 2011). Although both concepts have various definitions it is generally accepted that organisational climate relates to employees' shared perceptions of organisational conditions while organisational culture concerns deeper and more enduring underlying values and assumptions.

> Organisational culture is "*a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation (e.g. core mission, functions) and internal integration (e.g. common language, group boundaries, allocation of resources and rewards), that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems*." (Schein, 1990, p111)

Schein (1990) clarifies the distinction between organisational climate and culture with his description of organisational climate as the "*surface level manifestations of organisational culture"* (p109).

After a decade of, what Denison (1996) refers to as, the paradigm wars, he reviewed the two concepts and concluded that organisational climate and organisational culture were variations on a theme with the differences being differences in perspective, rather than phenomenon. The shared phenomenon according to Denison (1996) is the creation and influence of social contexts in organisations, to which both perspectives have made useful contributions. Schneider et al. (2011) agree that organisational climate and culture study the same phenomena although they describe that phenomenon as the 'psychological life of organisations'. Due to the commonality in research phenomenon and the importance of these concepts, Denison (1996) recommended that work from the two research paradigms be integrated rather than set in opposition. This is an argument that Schneider et al. (2011) are still making today.

Whilst the organisational climate/culture debate is continuing, work in this area is increasingly converging, with some claiming that organisational culture has superseded organisational climate, particularly as it now frequently utilises the quantitative research approaches traditionally associated with organisational climate (Glick, 1985; Guldenmund, 2000; Seo et al., 2004). The focus of the present study is organisational climate, as it represents the immediate manifestations of priorities and values that impact on workplace outcomes. However, although organisational climate has been studied for decades there is still much to comment on.

The role of organisational practices and procedures

Organisational practices and procedures hold a prominent place in organisational climate research as it has long been established that climate perceptions are formed on the basis of perceived or inferred events, practices and procedures (Schneider, 1975). There is also extensive empirical evidence from early climate research that climates can be altered through the manipulation of practices and procedures and that this manipulation leads to changes in behaviour (Schneider, 1975). Early climate research provides numerous examples that demonstrate that individuals adapt their behaviour to fit the environment. For example, Frederiksen, Jensen and Beaton (1972) created different climates by manipulating administrative procedures and supervisory style. They found that climate affected not only the level of performance but also patterns of performance (i.e. whether subordinates worked through supervisors or peers). Furthermore, these researchers demonstrated that performance improved when the administrative procedures and the supervisory style matched. For example, when innovative administrative procedures were paired with a global supervisory style and when rules based administrative procedures were paired with detailed supervisory style. Litwin and Stringer (1968) also demonstrated that they were able to manipulate the climate to produce particular outcomes. For instance, the creation of an achievement climate led to higher achievement while an affiliation climate led to greater innovation. Fleishman (1953) found foremen adapted their behaviour to the work climate so that it was consistent with the supervisor's behaviour rather than the behaviour taught in a training program. These early climate studies demonstrated that "*when everything else was held constant but climate behaviour changed*" (Tagiuri, 1968, p18).

More recent organisational climate research has tended to conduct survey research in real organisations rather than experimental research in a laboratory or simulated work setting. This research according to Ostroff (1993) and Parker et al. (2003) has been based on the assumption that employee climate perceptions affect both individual and organisational outcomes. Reviews by Parker et al. (2003) and Carr, Schmidt, Ford and DeShon (2003) identified that employee climate perceptions are associated with a number of individual (e.g. burnout, job performance, job satisfaction) and organisational outcomes (e.g. accident rates, customer satisfaction and financial performance). Parker's et al. (2003) meta-analytic review confirmed the relationships between employee climate perceptions and work attitudes, psychological well being, motivation and performance. Work attitudes were found to fully mediate the relationships between climate and motivation, and climate and performance. Carr et al. (2003) conducted a meta-analytic path analysis which suggested that organisational commitment and job satisfaction, which have well established relationships with climate, mediated the effect of climate on the individual level outcomes of job performance, psychological well being, and withdrawal.

Ostroff's (1993) study is important to highlight as she simultaneously examined the effects of both organisational climate and personal orientations on employee attitudes and behaviours. Both constructs were found to be significantly associated with the outcome variables. Organisational climate was related to satisfaction, commitment, adjustment, turnover intentions and absenteeism, while personal orientations explained variance independent of that explained by organisational climate. However, the interaction effects failed to explain additional variance.

Oz et al. (2010) recent organisational climate study involved 230 professional drivers from eight organisations and demonstrated that organisational climate predicted errors and violations, such that fewer errors and violations were committed by drivers from organisations that were perceived to have higher rather than lower work orientations (i.e. clear practices and an emphasis on standards). Greater consideration for employees was also associated with fewer errors and violations. However, the interaction of work orientation and employee consideration was found for violations, but not for errors. The Oz et al. (2010) study is an exception in recent organisational climate research in that it utilised the broad construct of organisational climate while most researchers now utilise a narrower construct, and focus on specific facets of organisational climate (Zohar & Luria, 2005).

Facets of organisational climate

Schneider (1975) advocated that organisations possess a myriad of climates, each one related to a specific domain of practices and procedures. His review of organisational climate research established that many climate researchers had already studied facet-specific climates rather than a general overall organisational climate. These facet-specific climates included leadership climate, motivation climate, service climate and creative climate. Moreover, specific climates (domains of practices and procedures) were related to specific types of behaviour with Seashore and Bowers (1970) advocating that it was necessary to alter whole sets of practices and procedures (e.g. practices and procedures concerned with leadership) in order to change the associated behaviour (e.g. leadership). Schneider (1975) consequently asserted that researchers should focus on facet-specific climates and study them intensely rather than attempting to study some compilation of climates supposedly representative of an overall organisational climate. His recommendation was that climates should relate to a particular research area (e.g. innovation) rather than an organisational level. Group goals were later suggested as a way to define facet-specific climates, with service climate for example defined by the goal of customer satisfaction (Schneider et al., 2000).

The overall organisational climate concept, although appealing, has come to be associated with such a proliferation of variables that it has frequently been criticised for being too broad and too abstract to be either meaningful or useful (Guldenmund, 2000). The narrower concept of facet-specific climates has proved to be a practical and popular approach to the study of organisational climate (James et al., 2008; Zohar & Luria, 2004). Furthermore, Carr et al.'s (2003) review of organisational climate research indicated that facet-specific climates were predictive of specific behaviours while few definitive conclusions had been drawn from research involving the broad organisational climate concept, despite decades of research. This is attributed to conceptual and methodological issues (Carr et al., 2003). Consequently, Carr et al. (2003) recommended that facet specific climates be utilised for studies of specific (e.g. safety behaviour) rather than general outcomes (e.g. job performance). According to Zohar & Luria (2005) organisational climate research has now focused on facet-specific organisational climates such as safety climate.

Safety Climate

Safety climate is one of the most prominent facets of organisational climate. However, it is a much confused and debated concept. Many of the issues prevalent in the organisational climate research are echoed in the research on safety climate. For instance, there is no one agreed upon definition or measure of safety climate and safety climate is also frequently confused with its culture counterpart. The two main definitions provided for safety climate also emulate the two strands of thought on organisational climate. One narrow and focused on procedures and practices that emanates from Schneider's (1975) organisational climate work while the other broader definition has links to Schein's (1990) work on organisational culture. These prevailing safety climate definitions are presented below:

"Safety climate refers to shared perceptions of policies, procedures, and practices relating to safety in the workplace" (Neal & Griffin, 2006, p946)

"Safety climate is a snapshot of the surface manifestations of the underlying safety culture" (Flin et al., 2000, p178)

Safety climate, like organisational climate, preceded its culture counterpart and was first highlighted by Zohar (1980) over thirty years ago. Safety culture was introduced six years later in the Chernobyl accident investigation report of 1986 (Naevestad, 2009; Silva, Lima & Baptista, 2004). Whilst the two concepts are frequently confused and sometimes used interchangeably (Silva et al., 2004), the difference between them is well explained by the analogy to psychological traits and states (Cox & Cheyne, 2000; Wiegmann, Zhang, Thaden, Sharma, & Gibbons, 2004). Safety culture is trait-like as it is an enduring characteristic representative of deep underlying safety values and assumptions. Safety climate is like a psychological state, in that it is reflective of the situation at a point in time but is subject to change dependent on operational and economic circumstances (Wiegmann et al., 2004). Safety climate is easier to measure and is the generally accepted focus of quantitative research involving measurement.

In the thirty years since Zohar (1980) first introduced the concept of safety climate there has been a proliferation of research in this area. Neitzel, Seixas, Harris and Camp (2008) claim that initial studies were conducted in what they termed to be fixed industry (e.g. manufacturing) but they maintain that safety climate research has since been extended to include dynamic industries such as construction. Recent reviews (e.g. Christian et al., 2009; Clarke, 2006) confirm that initial studies were conducted in manufacturing and chemical processing while safety climate research in industries such as construction, energy, health, service, communications and the military occurred later. The aviation industry however, was not represented in either Christian et al's., (2009) or Clarke's (2006) reviews and only one aviation study (Spanish study of airport ground staff) was identified in Flin et al.'s, (2000) review of safety climate research in the industrial sector. This apparent lack of safety climate research within aviation was also identified by Wiegmann et al., (2004).

Safety culture on the other hand, has greater ties to aviation due to its prominence in accident investigation reports. The aviation industry was alerted to the importance of safety culture in the early 1990s when it was identified as a crucial factor in two aviation accident investigations, one involving an American carrier, Continental airlines, in 1991 (Wiegmann et al., 2004), and the other a Canadian Air accident in 1992 (Hadden-Cave, 2008). Thus, the aviation industry is more familiar with the safety culture terminology and may favour its use. A search of research in this area has revealed that safety climate research has recently been initiated in aviation (e.g. Fogarty, 2004; 2005; Fogarty & Shaw, 2009; Neitzel et al., 2008) albeit at times under the guise of safety culture research (e.g. Ek & Akselsson, 2007; Gibbons et al., 2006).

Safety climate has now been extensively studied in a wide range of industries over three decades. This research has primarily been concerned with the relationships between safety climate and safety outcomes such as accidents and injuries. Safety performance (safety behaviours), which is comprised of safety compliance and safety participation (voluntary safety behaviour e.g. helping a colleague with a safety issue), is also commonly assessed as it is generally assumed that safety climate impacts on safety performance, which in turn impacts on safety outcomes (Neal & Griffin, 2006). Christian et al., (2009) and Clarke's (2006) recent meta-analyses demonstrated that a more positive safety climate was associated with increased safety performance, particularly increased safety participation, as well as fewer accidents and injuries. Moreover, Neal and Griffin's (2006) five year longitudinal study in an Australian hospital demonstrated that safety climate had lasting and lagged effects. Positive safety climate in year two was related to increased safety performance in year two, greater safety motivation in year four and fewer workplace injuries in year five.

Positive safety climates have also been demonstrated to be related to a number of other variables including increased safety knowledge (Christian et al., 2009); greater upward safety communication (Kath, Marks & Ranney, 2010); better safety practices (Zohar, 1980); fewer injuries and near misses (Seo, Torabi, Blair & Ellis, 2004); fewer medication errors, and greater patient and nurse satisfaction (Hoffmann & Mark, 2006). In Aviation maintenance environments, positive safety climates have been correlated with higher morale (Fogarty 2004), lower turnover (Fogarty 2004) better psychological health (Fogarty 2004; 2005; Fogarty & Buikstra, 2008), and greater safety compliance, both self reported (Fogarty & Buikstra, 2008) and observed (Neitzel et al., 2008). Safety climate has also been related to errors but this relationship has been shown to be mediated by violations and psychological health (Fogarty & Buikstra, 2008). The interrelationships between safety climate and the three outcome variables of violations, psychological health and errors are illustrated in Figure 6 and will be discussed further in the next section in the context of error climate.

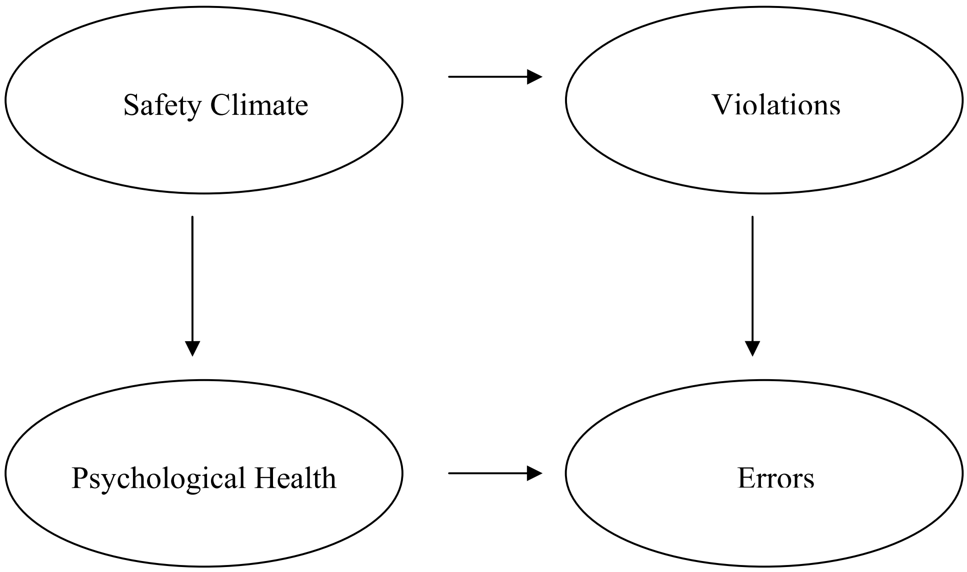


Figure 6: Empirical model emphasising safety climate relationships with psychological health, violations and errors (adapted from Fogarty & Buikstra, 2008)

Error Climate

Error climate which refers to employees' shared perceptions of organisational practices regarding errors (Van Dyck et al., 2005), was not originally conceptualised in a safety context but was recently defined as a facet of safety climate by researchers working in the safety arena (e.g. Cigularov, Chen & Rosecrance, 2010; Hofmann & Mark, 2006; Hughes et al., 2009).

The importance of good error management has been gaining impetus in recent years and is now advocated to be an essential element of safety (Hadden-Cave 2008; Helmreich 2000; Hughes et al., 2009; Reason 1997; Reason & Hobbs 2003). However error management, which has traditionally been studied independently of safety climate, is yet to be incorporated into mainstream measures of safety climate which still reflect the error prevention approach dominant at the time of Zohar's (1980) landmark paper. That is, mainstream measures emphasise the existence of and adherence to safety rules and regulations and equate this with a good safety climate without acknowledging the importance of effective error handling (Hoffman & Mark, 2006). Hoffman and Mark (2006) attempted to rectify this situation and amalgamate the two strands of research by being the first to incorporate components of error climate into a broader conceptualisation of safety climate. These researchers demonstrated that components of error climate (e.g. thinking about errors, willingness to reveal errors and error communication), whilst distinct from traditional safety climate factors (e.g. job duties, management attitude toward safety), belonged to the same overarching concept.

Hoffman and Mark (2006) demonstrated that this composite measure of safety climate predicted important safety outcomes in a medical setting including medication errors, urinary tract infections and workplace injuries. Cigularov et al. (2010) also demonstrated the importance of error climate to safety, this time in the construction industry, finding that EMC had a significant negative effect on work-related pain (e.g. neck pain) and a significant positive effect on safety behaviours, both task (e.g. reporting accidents) and contextual (e.g. citizenship behaviours such as attending safety meetings).

Error climate was related to willingness to reveal errors in the healthcare industry (Edmondson, 1999). Edmondson (1999) demonstrated that employees were more likely to discuss and reveal errors in non punitive environments where errors were seen as a natural occurrence rather than punitive environments where errors were a reflection of employee incompetence. Safety researchers have long recognised the importance of non punitive work environments and the aviation industry adopted this approach many years ago (Helmreich, 2000). However, a blame culture is still evident in other safety-focused environments, such as healthcare, and this is hampering safety efforts as there is a general reluctance to reveal errors and relatively high error rates in healthcare (Edmondson 1999; Hughes et al., 2009; Hoffman & Mark, 2006).

Willingness to reveal errors, or, in its negative form, covering up errors, is a facet of error climate that is particularly important in safety. This is one of the more frequently studied components of error climate and was one of the components included in Hoffman and Mark's (2006) composite measure of safety climate. One reason for the significance of this facet is that willingness to reveal error has been shown to be related to the ability to detect error (Edmondson, 1999). Willingness to reveal error has also been shown to vary as a function of unit leader openness to discussing error (Edmondson, 1999). Units with leaders who scored high on openness were more willing to reveal errors and detected substantially more errors than average. Conversely, units whose leaders were low on openness were reluctant to reveal error and detected fewer errors than average. The unit with the highest error detection rate achieved a rate ten times higher than that of the unit whose leader was particularly low on openness.

Error climate has been shown to vary significantly across units within organisations. Edmondson (1999) and more recently Hughes et al. (2009) found significant differences in error climate within hospitals. Hughes et al. (2009) revealed that smaller units and units that had fewer interruptions and unanticipated events had better error climates and were more likely to communicate about error, reveal error and participate in error-related problem solving than larger units or units with greater complexity. Better error climates were also found in hospitals that supported nurse autonomy and encouraged participation in decision making (Hughes et al., 2009).

Hughes et al. (2009) found that in contrast to much of the safety climate research the workgroup, more so than management, was the primary determinant of safety climate (as measured by Hoffman and Mark's composite measure of safety climate). Edmondson's (1999) quantitative and qualitative data on the other hand, suggested that the primary determinant of error climate was unit leader openness to discussing error. Units held shared perceptions of the consequences of committing errors and these perceptions guided behaviours in relation to discussing, revealing, detecting and learning from error. The workgroup was therefore described as reinforcing the error climate created by the leader.

Two types of error climate, error management climate (EMC) and error aversion climate (EAC) were originally identified by Van Dyck et al. (2005). EMC was conceptualised as the opposite of an EAC and is described as one in which *"employees perceive that there are organisational practices related to communicating about errors, to sharing error knowledge, to helping in error situations and to quickly detecting and handling errors*" (Van Dyck et al., 2005, p 1229). An EAC on the other hand, is characterised by a fear of error and a reluctance to discuss error (Van Dyck, 2008).

The two types of error climate are based on the two approaches to error discussed in Chapter Two. EAC is based on the error prevention approach while EMC is based on the error management approach (Rybowiak et al., 1999). A combination of these two approaches led to a third type of error climate, theorised as being the ultimate error climate and referred to by Van Dyck (2008) as an error mastery climate. Van Dyck (2008) claimed that on a continuum of error climates, EAC was the extreme negative end of the continuum, while error mastery climate, which combines a realistic focus on error prevention with an emphasis on error management, represented the opposite extreme (Figure 7). EMC, although not stipulated in Van Dyck (2008), would be towards the positive end of the spectrum.

Error Mastery Climate
Realistic focus on error prevention combined with an emphasis on error management

Error Aversion Climate
Rigid focus on error prevention and a fear of making errors

Figure 7: Continuum of Error Climates

Van Dyck (2008) presented examples of the beliefs that underpin these extremes and the reinforcements and behaviours that represent the manifestations of these beliefs (Table 2).

Table 2: Three Layers of Error Mastery and Error Aversion Climates

	Deepest layer: Examples of beliefs	**Middle layer:** Examples of reinforcements	**Superficial layer:** Examples of error behaviour
Error Mastery Climate	To err is human The important thing is good error handling	Rewarding constructive error handling	Detection, correction, learning Open communication
Error Aversion Climate	Errors are a sign of incompetence We don't make mistakes	Punishment of error occurrence	Strain caused by errors Covering up

(adapted from Van Dyck, 2008)

According to Van Dyck (2008) the underlying premise of an EAC is intolerance towards errors and a belief that errors represent incompetence. This is in keeping with the traditional view of errors which focuses on individuals and fails to differentiate between errors and violations. In an EAC errors are treated as though they were deliberate and employees are punished for their mistakes (Van Dyck., 2008). The resulting climate is characterised by a fear of errors, placing additional strain on employees and encouraging the concealment of errors. EACs are normally associated with bureaucratic hierarchal organisations (Van Dyck et al., 2005).

EMCs in contrast hold similar beliefs to that of error mastery climates in that errors are considered to be normal, inevitable and informative as well as distinct from error consequences and violations. Errors are taken seriously but the focus is on the quick detection and correct handling of error rather than the rigid prevention of error (Edmondson, 1999; Van Dyck et al., 2005). Errors are openly discussed and analysed so that they can be quickly detected and resolved and an emphasis is placed on learning at both an individual and organisational level. EMCs have been found in a variety of industries and have been associated with higher organisational performance as well as better safety outcomes (Cigularov et al., 2010; Hoffman & Mark, 2006; Van Dyck et al., 2005)

As error climate research is only in its initial stages, there appears to be only one empirical study involving both EMC and EAC constructs, that of Van Dyck et al. (2005) the study from which the concept originated. Van Dyck et al. (2005) studied 65 Dutch organisations and found quantitative and qualitative evidence of EMCs and EACs across a wide range of industries and departments. A research question that was proposed was that EMC and EAC would be negatively correlated. However, this supposition was not supported as the result did not reach statistical significance. These results may not have provided a strong test of this research question though as Van Dyck et al. (2005) did not study safety related errors. Safety related errors have more serious consequences and their correct error handling and disclosure is of extreme importance. As such it is likely that in safety environments such as aviation maintenance, the result would be more pronounced. It is therefore proposed that in the present study a negative relationship between EMC and EAC will be found.

H1: EMC will be negatively correlated with EAC

The present study aims to demonstrate that error climate is an important organisational factor with significant safety implications. As errors and violations are important precursors of safety outcomes (e.g. incidents, injuries and accidents), this study seeks to determine the associations between error climate and, errors and violations in the context of a military aviation maintenance environment where safety is paramount. It is proposed that an EMC will be associated with fewer errors as secondary errors will be prevented through the open discussion and analysis of error and the emphasis on learning from error. Conversely, an EAC will be associated with more errors as secondary errors will increase due to the lack of discussion and learning about error and lower levels of error detection.

H2a: EMC will be negatively correlated with error

H2b: EAC will be positively correlated with error

The relationship between error climate and violations will be discussed later when the links to the proposed empirical model presented at Figure 8 are justified and discussed.

As error climate is a relatively new concept there are few empirical studies involving error climate and there are no empirical models. Empirical models are also rare in safety climate research however those that do exist have been useful for identifying precursors to unsafe acts and explaining associations between variables. The model for the current study (Figure 8) has therefore been taken from safety climate research and is utilised on the understanding that error climate is a facet of safety climate. This model is an adaptation of the Fogarty and Buikstra (2008; Figure 6) model which was based on the Reason (1997) model of unsafe acts, that is well known in aviation. It has been chosen as the basis for the model employed in this study as it is the latest iteration of a model of unsafe acts that has been developed and tested in an Australian military aviation maintenance environment. It is also the first empirical model to incorporate both errors and violations as independent links. Moreover, the link between safety climate, psychological health and errors has been replicated in a previous study in a similar context (Fogarty, 2005). Fogarty and Buikstra's (2008) model also successfully explained a large amount of the variance in aviation maintenance errors (58%) and violations (63%).

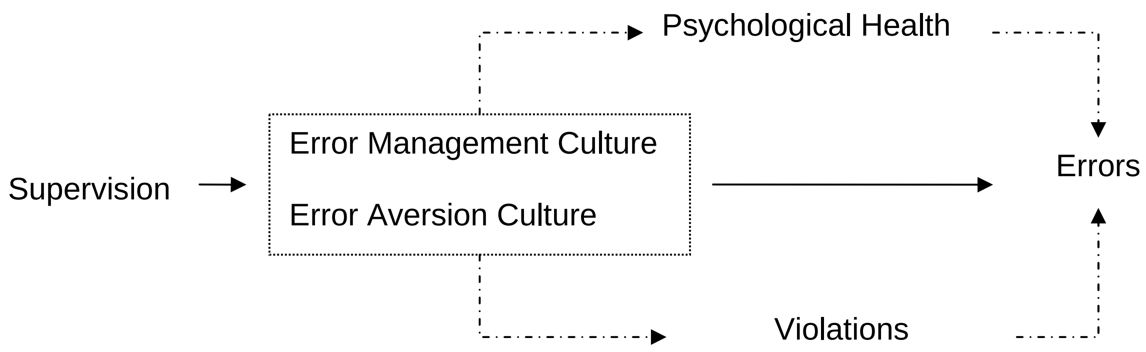


Figure 8: Theorised model of associations for the current study

This study will determine the associations between error climate, supervision, individual psychological health, and self reported aviation maintenance errors and violations. Each of these links will now be justified and discussed.

Supervision

The distinguishing characteristics of positive safety climates are now well known and include management commitment to safety, supportive supervision, workgroup trust, open communication, empowered employees, reward and evaluation systems that promote safety in a fair and consistent manner, effective reporting and feedback systems, an integrated approach to safety, effective safety protocols and a learning orientation (Reason, 1997; Wiegmann, 2004; Zohar, 1980). Zohar's (1980) initial literature review also highlighted another important distinguishing characteristic of organisations with low accident rates: they promote safety through guidance and counselling, rather than enforcement and admonition and give individual praise or recognition for safe performance.

Supervisors have long been known to play a pivotal role in safety and this claim is further supported by recent research (e.g. Oliver et al., 2002; Simard & Marchard, 1997; Zohar & Luria, 2005; Zohar, 2008). The introduction of the safety climate construct and the advent of the organisational culture period of accident causation theories in the 1980s highlighted and reinforced the importance of the supervisor role in safety and accident prevention. More recent research has indicated that the supervisor may even play the most influential role due to the supervisor's close proximity to the workgroup. For example, Simard and Marchard (1997) found that micro (e.g. workgroup characteristics) rather than macro factors (e.g. top management commitment) and supervisory practices in particular, had the greatest influence on safety compliance. Furthermore, research by Zohar and Luria (2004) suggested that supervisory decisions regarding the prioritisation of safety over production predicted safety climate level (i.e. the perceived priority of safety over production) and the consistency of those decisions predicted climate strength (within group variability). Safety climate research, as with organisational climate research, has a strong focus on rules, procedures and practices. Safety protocols, particularly enacted safety protocols, are thought to guide behaviour, with employees prioritising their behaviour to reflect their perceptions of the organisation's priorities. If a priority of operations over safety is perceived or inferred, that will guide employee behaviour toward satisfying operational rather than safety requirements (Zohar & Luria, 2005).

High quality relationships between supervisors and workgroups, along with the supervisor's propensity to participative management (supportive supervision), have been identified as the most influential factor in safety (Simard & Marchard, 1997). Trust between the supervisor and the workgroup, as well as trust within the workgroup, are also highlighted as being essential to safety in the aviation maintenance environment (Taylor & Thomas, 2003). Furthermore, supportive supervision and management commitment to safety have been found to impact on other safety climate dimensions and are purported to be the most important characteristics of a good safety climate (Seo et al., 2004).

The supervisors' significance in safety is reflected in the frequency with which supervisor factors feature in safety climate measures and human factors models. According to a review by Flin et al. (2000), supervisor competence is the second most frequently measured dimension after management attitude towards safety. Supervisor factors also feature highly in human factors models that have been applied to aviation accidents such as the SHELL Model (Hawkins, 1993) and the Human Factors Analysis and Classification System (HFACS).

Open communication and frequent interactions between supervisors and subordinates have long been identified as key characteristics in accident prevention. These characteristics prevent accidents in that they create opportunities for the discussion of errors and thereby facilitate the early detection and correction of error. The level of influence of the supervisor however, is to a degree dependent on the level of discretion afforded to the supervisor (Zohar & Luria, 2004). Supervisors have limited discretion in the interpretation and implementation of safety protocols when they are highly formalised and prescribed. Aviation maintenance is a highly regulated profession however it is also a profession in which the conflict between safety and production is paramount.

Supervision and error climate are expected to be highly related as culture and leadership are two sides of the same coin (Schein, 2004) and supervisors are key leaders in safety. This close relationship is further anticipated due to the finding of

Hoffman and Mark (2006) that traditional safety climate dimensions such as supervisor competence and dimensions of error climate are distinct but related facets of safety climate. Whilst error climate is likely to be influenced by a number of variables there is evidence to suggest that supervisors are instrumental in shaping the error climate of their team (Edmondson, 1999).

Cigularov et al. (2010) recently implied that supervisors could be an effective means through which to improve EMC. As Error Climate is a new concept this suggestion was based on the success of an intervention in Zohar and Luria (2003) that demonstrated the influence of supervisors on employee perceptions of safety climate and safety compliance behaviours. More direct evidence of the influence of supervisors on error climate is provided by Fischer et al. (2006) who noted claims from medical students that responses to error (e.g. openness or defensiveness) and consequences of error (e.g. learning, ridicule, stress) were dictated by supervisor personality. These claims are supported by qualitative evidence in Edmondson (1999) which demonstrated that employee perceptions of and responses to error were influenced by supervisor attitudes towards errors. For example, leaders who saw errors as learning opportunities and who were high on openness tended to have staff who perceived errors as normal but important to document and discuss. Leaders who were low on openness and who took a punitive approach to errors on the other hand tended to have staff that perceived errors to be a threat and who were fearful of making and discussing errors.

Edmondson (1999) also made the crucial finding that willingness to report errors, which is a key component of error climate and an important factor influencing the detection of errors, varied systematically with the perceived openness of unit leaders. Subordinates who had unit leaders who scored high on openness were more willing to reveal and discuss errors. These units also had higher error detection rates and a greater number of interceptions by team members to correct errors. Error detection rates and interceptions were both shown to be positively related to supervisor direction setting and coaching in Edmondson (1999).

The time taken to detect errors and the number of errors detected and corrected has important implications for the consequences of errors which in industries such as aviation can be grave. Subordinates who are uncomfortable or afraid of reporting errors may try to deal with errors by themselves. If they are successful, the positive error consequences (e.g. learning) are limited as the error is not reported or shared. If they are unsuccessful in dealing with the initial error they may as Edmondson, (1999) claims only report the error when the situation becomes so dire that they feel they have no other choice. Consequently, when supervisor openness is low and subordinates are reluctant to reveal errors, errors are less likely to be detected and those that are detected are detected late when the consequences of the error are likely to be far more severe. Edmondson (1999) demonstrated that willingness to report errors and error detection and interception rates differed across teams within the same hospital lending further support to the idea that supervisors have a significant influence on these factors.

The results of another study in the healthcare industry, suggested that supervisors who took a participative approach to decision making and who supported the autonomy of subordinates had a positive influence on two other facets of error climate: error communication and error related problem solving (Hughes et al., 2009). These results are consistent with other studies (e.g. Simard & Marchard, 1997) that have highlighted the importance of a participative approach to supervision in safety environments. High quality relationships between supervisors and subordinates are of particular importance in safety as they have been found to be positively related to safety compliance, safety communication and safety citizenship behaviours and negatively related to accidents. It is therefore proposed that high quality supervision will be positively correlated with EMC and negatively correlated with EAC.

H3a: Supervision will be positively correlated with EMC

H3b: Supervision will be negatively correlated with EAC

Psychological Health

Psychological health refers to an individual's psychological well being. In this study it is represented by stress, fatigue and general psychological health. Other studies have utilised terms such as psychological strain, happiness and well being to represent a similar construct.

> Stress is defined as "*a relationship between the person and the environment (stimulus) that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being (response)*"
>
> *(Lazarus, 1984, p19)*

> Fatigue is not well defined in the literature but is generally taken to refer to physical or mental tiredness. It is characterised by a lack of alertness that may be brought on by a lack of sleep or work overload.

> General psychological health is related to the balance between positive and negative affect and the ability to deal with life's challenges (Keyes, Shmotkin & Ryff, 2002). Those in poor psychological health are characterised by "*a disruption in the performance of their daily life activities and the experience of subjective distress*" LoBello (1995)

Psychological health has traditionally been associated with individual characteristics such as personality factors. However, there is also evidence that psychological health is impacted by the work environment. Longitudinal studies for example, have demonstrated that psychological health varies over time along with characteristics of the work environment (e.g. Wright, Bonett & Sweeney, 1993). It is also well known that organisational factors such as the physical work environment, shift schedules, workload, work hours, work transitions and staffing limitations impact on employee health and well being (Hobbs & Williamson, 2003; Sussman & Coplen, 2000). This is further demonstrated in the work/life balance literature which shows that work characteristics impact on health and happiness outside of work.

This point, that organisational factors impact on employee health is also emphasised by the relationship between safety climate factors and employee psychological health (Fogarty, 2004; 2005; Fogarty & Buikstra, 2008; Oliver et al., 2002). Poor safety climates have a negative impact on the psychological health of employees while good safety climates have the opposite effect.

It is proposed that EMC will be associated with better psychological health in the current study as EMCs are characterised by favourable work characteristics such as good supervision, effective communication, intrinsic rewards, and support and trust that are known to have a negative relationship with stress and ill health (Cropanzano & Wright, 2001; Edmondson, 1999, Van Dyck et al., 2005). Furthermore, characteristics associated with higher levels of stress, such as a lack of input into decision making, are less likely to present in an EMC. As a result EMCs are likely to be happier environments and employees working in such climates will have better psychological health, which in the current study will be represented by lower levels of psychological health as the measure is a measure of ill health.

EAC on the other hand, is likely to be related to poor psychological health as these climates are lacking in the characteristics that have been associated with better psychological health such as communication, support and trust (Edmondson, 1999). These is also likely to be a lack of job autonomy and input into decision making in EACs and both these factors have a known relationships with stress (Cropanzano & Wright, 2001). Furthermore, EACs enhance the negative consequences of errors which include frustration, stress and negative attributions. Feelings of guilt or shame may also be provoked when errors are covered up which is likely to have a negative impact on psychological health. Additional evidence that an EAC will be associated with higher levels of psychological health (measure of ill health in the current study) comes from Rybowiak et al.'s (1999) finding that a key component of EAC, error strain, was positively correlated with general psychological health factors.

H4a: EMC will be correlated with lower levels of Psychological Health

H4b: EAC will be correlated with higher levels of Psychological Health

Psychological health has been widely studied as a precursor of error and performance (Cropanzano & Wright, 2001; Fogarty, 2004; Oliver et al., 2002). It is a key theory in organisational psychology that a happy worker is a productive worker and there is evidence to support the claim when happiness is operationalised as psychological well being (Cropanzano & Wright, 2001). Furthermore, accident investigations have highlighted the role of fatigue in operator errors, and stress and fatigue are well recognised in the aviation industry as a cause of error and have been prominent topics in human factors training in aviation for decades (Helmreich, 2000; Reason & Hobbs, 2003; Wiegmann & Shappell, 2001). As a result aviation professions are more willing to acknowledge the effects of stress and fatigue on performance than some other professions (Helmreich, 2000). The relationship between fatigue, stress and error is well document in a number of industries (e.g. healthcare, aviation, transportation) and is evidenced in policies and regulations regarding shift lengths and rest periods (May & Baldwin, 2009; Michielsen, Vris & Van Heck, 2003; Sussman & Coplen, 2000). Therefore it is expected that psychological health will be positively correlated with error in the current study.

H5: Psychological Health will be positively correlated with error

Psychological health has been demonstrated to mediate the relationships between organisational variables and safety outcomes. Oliver et al. (2002) for example, found that psychological health mediated the effects of organisational and environmental variables on occupational accidents. Other studies, in a military aviation maintenance environment, similar to that of the current study, have demonstrated that psychological health mediated the relationships between safety climate and maintenance errors (Fogarty, 2004; 2005; Fogarty & Buikstra, 2008). These studies suggest that psychological health would also mediate the relationship between error climate and errors. It is therefore proposed that psychological health will mediate the relationship between error climate and error in the current study.

H6a: Psychological Health will mediate the relationship between EMC and errors

H6b: Psychological Health will mediate the relationship between EAC and errors

Violations

Alper and Karsh (2009) claim that there are two ways to view violations. The traditional and dominant view is that violations are the actions of 'bad' individuals while the more contemporary view, that they advocate, is that violations are symptoms of systems issues. EMCs are likely to be more closely aligned with the latter view given that this view is similar to the founding beliefs of EMCs that errors are common, inevitable and informative. It is reasoned that this view will be associated with fewer violations as it frames workers as part of the solution rather than the problem and recognises them as a valuable source of information. This view also mitigates the threat associated with raising and discussing issues related to violations, increasing the chances that this will occur and that issues will be resolved. This is important as workers may hold the key to identifying systems issues that induce violations given that violations are consciously committed after an evaluation of the pros and cons of such actions have been considered (Battmann & Klumb, 1993). This view is also likely to be the more effective approach to violations as according to Alper and Karsh's (2009) review, systems issues have more interesting significant effects on violations than individual characteristics, and system factors, unlike individual characteristics, are within the organisation's control.

As EMCs are also typified by the open discussion of error, a problem solving approach to error and a learning orientation toward error, it is reasoned that in an EMC there will be many opportunities for workers to raise and discuss issues related to violations and to be involved in investigating and developing solutions to resolve issues that induce violations. As a result, EMCs are likely to have a negative relationship with violations as the systems causes of violations (e.g. lack of information, competing goals, ineffective work designs, unworkable rules and poor safety climate) identified in Alper and Karsh's (2009) review, are less likely to exist in an EMC. Further support for the idea that an EMC will be negatively related to violations comes from Cigularov et al.'s (2010) finding that EMC was positively related to the safety behaviours of construction workers.

An EAC on the other hand, which is theorised as the opposite of an EMC, is likely to be more closely aligned with the traditional view that violations are the actions of 'bad' individuals as this view is consistent with the error prevention approach that is taken for errors. As such, individuals are less likely to come forward about work issues that may be inducing violations or be in situations where such issues may be discussed. Furthermore, as violations are likely to be concealed, even from peers, it is less likely that common factors inducing violations will be identified and resolved. For example, workers may be unaware that a particular step in a task is commonly skipped as it is not discussed for fear of inciting trouble. Consequently, the reason for the violation will not be identified or discussed and the opportunity to resolve the issue will be lost. Also, workers in an EAC may be afraid to seek clarification of rules incase they are somehow implicated as a rule breaker or alternatively, rule justification may not be provided as it is considered redundant in such a climate and without this additional information workers may deem certain rules unnecessary or inconsequential and break them when in fact there are significant implications if they are contravened. The systems causes of violations identified in Alper and Karsh (2009) which include unworkable procedures, rule deficiencies, competing goals and insufficient information are therefore more likely in EACs. Hence, it is proposed that EACs will be positively related to violations.

H7a: EMC will be negatively correlated with violations

H7b: EAC will be positively correlated with violations

Violations are generally committed under the assumption that doing so is harmless or inconsequential. This view is supported by objective data from Line Operations Safety

Audits (LOSA) of normal flights which found that although violations were more frequently committed by aircrew than any type of error, only a very small percentage (2%) of violations became consequential (Helmreich, 2000). This finding that the majority of violations are inconsequential is supported by other research (Alper & Karsh, 2009). However, the LOSAs also found that the individuals who committed violations made 25% more errors than those who did not commit violations (Helmreich, 2000). Research in aviation maintenance has also demonstrated that violations lead to errors (e.g. Hobbs & Williamson, 2002; Fogarty & Buikstra, 2008; MacDonald et al., 2000).

There are a number of ways in which violations lead to error. Firstly, violations take employees outside the boundaries of normal operation and into less familiar territory where they are more prone to error (Naikar & Saunders, 2003). Secondly, a violation may remove or reduce defences designed to catch errors (Naikar & Saunders, 2003). For example, the opportunity to pick up errors in the latter stages of the job may be lost if a supervisor signs off maintenance work before it is finished (Parke & Kanki, 2008). Thirdly, violations may lead others to make incorrect assumptions that provoke errors (Reason & Hobbs, 2003). This is one reason errors are so prevalent after shift turnovers (Hobbs & Williamson, 2003; Parke & Kanki, 2008). For example, if a supervisor in the first shift has signed off a job, the second shift will assume that it has been completed without error. If the first shift has not recorded its work correctly the second shift may assume work has been finished that is still ongoing or vice versa. Furthermore, if a technician goes to carry out work on an aircraft and there are no warning signs to indicate that he should not, he may carry out his work as normal and consequently make an error. Finally, violations that occur frequently have a tendency to become normalised and automatic, meaning that employees may no longer make a conscious assessment of the risk and therefore they may fail to take the necessary precautions to avoid error (Lawton, 1998). New employees for example, may understand that a particular step is always skipped however they may not understand the implications of the violation and therefore may fail to take the necessary precautions to carry out the violation without error. Moreover, employees may generalise the violation of one rule to other rules until they come to assume that it is okay to break the rules or that a careless approach to work is acceptable, which the effect that errors are increased as both assumptions invite error (Lawton, 1998). Violations have been implicated in most accidents but the relationship with accidents has been shown to be indirect through error (Reason & Hobbs, 2003). It is therefore proposed that violations will be positively correlated with errors in the current study.

H8: Violations will be positively correlated with errors

One of the main causes of violations identified in safety research is safety climate (e.g. Alper & Karsh, 2009; Neal & Griffin, 2006; Fogarty & Buikstra, 2008). Safety climate studies demonstrate that when management policies and practices in particular, do not emphasise or support safety compliance or prioritise safety, violations will occur as employees will perceive for example that operations (production) are more important than safety and prioritise accordingly. Fogarty and Buikstra (2008) demonstrated that safety climate had a direct relationship with violations in an aviation maintenance environment in the Australian Defence Force. These researchers also demonstrated that violations mediated the relationship between safety climate and errors. As climate factors tend to have distal relationships with safety outcomes such as errors, injuries and accidents (Christian et al., 2009), it is reasoned that the relationship between error climate and errors will also be mediated by violations in the current study.

H9a: Violations will mediate the relationship between EMC and errors

H9b: Violations will mediate the relationship between EAC and errors

Summary of Hypotheses:

1: EMC will be negatively correlated with EAC

2a: EMC will be negatively correlated with errors

2b: EAC will be positively correlated with errors

3a: Supervision will be positively correlated with EMC

3b: Supervision will be negatively correlated with EAC

4a: EMC will be correlated with lower levels of Psychological Health

4b: EAC will be correlated with higher levels of Psychological Health

5: Psychological Health will be positively related to errors

6a: Psychological Health will mediate the relationship between EMC and errors

6b: Psychological Health will mediate the relationship between EAC and errors

7a: EMC will be negatively correlated with violations

7b: EAC will be positively correlated with violations

8: Errors will be positively correlated with Violations

9a: Violations will mediate the relationship between EMC and errors

9b: Violations will mediate the relationship between EAC and errors

Chapter Four: Method

The current study employed a quantitative research approach with a single cross sectional survey design to assess the associations between variables. The independent variables were error climate (EMC and EAC), supervision and psychological health (as measured by stress, fatigue and general health). The dependent variables were self reported errors and violations. Scales were computed as item means.

Participants

The participants were all Royal New Zealand Air Force (RNZAF) Technical Trade personnel below the rank of Flight Sergeant[2] who had completed their Mechanics Course and were working on a Force Element Group (FEG - 5 Squadron, 6 Squadron, 40 Squadron) or within Maintenance Wing (Maintenance Support Squadron or Avionics Squadron) in either Whenuapai or Ohakea[3]. This group encompassed 524 Technical personnel (approximately half of the Technical personnel in the RNZAF) covering four of the six rank levels and the full gamut of Technical Trade specialisations (Aircraft, Avionics, Armament, Safety & Surface, and the Small Technical Trades[4]). The research questionnaire was completed by 189 participants representing a response rate of 36%.

Limited demographic data covering Position (e.g. Mechanic, Technician), Trade (e.g. Aircraft Technician) and Squadron (work unit e.g. 6 Squadron, Avionics Squadron) was collected due to organisational constraints. The majority of participants were fully qualified Technicians with the remaining 23% Mechanics (non qualified Technicians) completing on the job training. The two main trade specialisations, Aircraft Technicians and Avionics Technicians, constituted 74% of participants while the remaining 26% were Technicians from the Small Trades (Small Technical Trades, Armament and, Safety & Surface). Fifty-five percent of participants were from the FEGs while 45% were from

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[2] These are the ranks that perform practical maintenance activities on the units

[3] A description of the organisation, Technical units and personnel, including rank structure, is provided in Appendix A.

[4] The different Technical Trades are outlined in the Glossary.

Maintenance Wing. This slight overrepresentation of the FEGs is to be expected as the questionnaire was most relevant to this group. Table 3 compares the participant data with the personnel data from the units involved in the research. This sample is representative of the population although Senior Non Commissioned Officers (SNCOs - Maintenance supervisors), Avionics Technicians and participants from the FEGs were overrepresented.

The average organisational tenure of Technical personnel on the researched units is displayed in Table 3 by position (rank). Using this data it is possible to calculate that the average tenure of participants was approximately 8 years[5]. The average age of Technical personnel on enlistment is 19 years and 9 months[6] which suggests that the average age of participants was approximately 27 years. All participants were over 17 years of age and most were New Zealand citizens as these are enlistment requirements for the RNZAF although some exceptions are made for citizenship (NZAP 252 Manual of RNZAF Recruiting Administration, 2000). RNZAF Technical personnel are predominately NZ European males, with 87% NZ European, 5% Maori, 2% Asian, 1% Pacific Peoples and 5% of other ethnicity or an unspecified ethnicity. Only 5% of the Technical personnel on the researched units were female suggesting that at least 86% of participants were male and most were NZ European.

Although Technical personnel move between practical maintenance and Technical policy roles during their RNZAF careers, only Technical personnel who were currently in practical maintenance roles were eligible to participate as questionnaire items referred to recent practical maintenance errors and violations. Personnel participated in response to an email invitation from the researcher through their chain of command. Participants were advised when accessing the online questionnaire that completing and saving the questionnaire implied consent, and that participation was voluntary and confidential.

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[5] Tenure increases with rank as personnel within the military are grown and cannot be brought in from outside the organisation to fill higher level positions unless they are re-enlisting in the NZDF or joining from an overseas Military.

[6] 19 years and 9 months was the consistent average age on enlistment of Technical personnel over the ten years to 2010 - RNZAF Workforce Planning.

Table 3: Demographics

		Participants		Personnel		Tenure in RNZAF of Technical Personnel on research units
		No.	%	No.	%	(Years)
Position	Position, in decreasing seniority (Rank)					
Qualified Technicians	Senior Non Commissioned Officers, SNCOs (Sergeant, SGT)	65	34.5%	128	24%	12.8
	Junior Non Commissioned Officers, JNCOS (Corporal, CPL)	46	24%	124	24%	8.9
	Technicians (Leading Aircraftsman, LAC)	34	18%	129	25%	4.9
Mechanics	Mechanics (Aircraftsman, AC)	43	23%	143	27%	2.3
(Non qualified Technicians)	Missing Data	1	.5%			
	Total Sample	*189*	*100%*	*524*	*100%*	
Trade	Aircraft	67	35%	221	42%	
	Avionics	71	38%	145	28%	
	Small Trades (Small Technical Trades, Armament, Safety & Surface)	49	26%	158	30%	
	Missing Data	2	1%			
	Total Sample	*189*	*100%*	*524*	*100%*	
Squadron						
Force Element Groups	5 Squadron (Maritime)	30	16%	68	13%	
	6 Squadron (Naval Support Helicopters)	32	17%	55	11%	
	40 Squadron (Transport)	41	22%	84	16%	
Maintenance Wing	Maintenance Support Squadron (MSS)	51	27%	317[7]	60%	
	Avionics	31	16%			
	Missing Data	4	2%			
	Total	*189*	*100%*	*524*	*100%*	

Personnel and tenure statistics were provided by RNZAF Workforce Planning.

[7] This figure is the overall figure for Maintenance Wing

Measures

EMC: EMC was measured by 16 items e.g. "*When people make an error, they can ask others for advice on how to continue*" (Van Dyck et al., 2005). Participants responded with reference to their workplace in the RNZAF on a scale that ranged from 1 (never) to 5 (always) for 15 items and from 1 (strongly disagree) to 5 (strongly agree) for one item that did not fit the never/always response format. The overall score was the mean of the 16 items ($\alpha = 0.81$). Higher scores reflected a more positive EMC.

EAC: EAC was measured by 11 items covering two facets of EAC which explained 55% of the variance in EAC scores (for factor analysis see Appendix C): Error Strain, 5 items; e.g. "*People in this organisation are often afraid of making errors*" and Covering up Errors, 6 items; e.g. "*Our motto is, why admit an error when no one will find out*" (Van Dyck et al., 2005). Participants responded with reference to their workplace in the RNZAF on a scale that ranged from 1 (never) to 5 (always) for nine items and from 1 (strongly disagree) to 5 (strongly agree) for two items that did not fit the never/always response format. Scale reliabilities were good for total EAC ($\alpha = 0.84$), Error Strain ($\alpha = 0.81$) and Covering up Errors ($\alpha = 0.80$). Scale scores were computed as the means of items, such that higher scores reflected a more negative EAC, greater error strain and a greater willingness to cover up errors.

Participants were not provided with a definition of error. However, at the end of this section participants provided examples of the errors they had thought about while responding to EMC and EAC items. Examples of error information provided by participants are provided in Table 5 in the Results section (Chapter 5).

Supervision

The standard of supervision was measured by 6 items from the Maintenance Environment Survey, MES, Version 1 e.g. "*I trust my supervisor*" (Fogarty, 2004). Participants responded with reference to their immediate supervisor on a scale from 1 (strongly agree) to 5 (strongly disagree). The MES was developed for use with Australian Army

Maintenance Engineers working on helicopter repair bases. The score was the mean of the six items and higher scores reflected a better standard of supervision (α= 0.82).

Psychological Health

The Psychological Health measure comprised three subscales from the MES, Version 3: Stress, Fatigue and General Health (Fogarty & Buikstra, 2008). Lower scores on the three subscales indicated better psychological health.

> *Stress*: Each item began with the stem "*How often do you feel stressed at work because of….* "(e.g. "*…the task itself*"; 1 = Never to 5 = Always). One item ("*…problems outside of work*") did not refer to work related stress and was removed to improve reliability. The score was the mean of the four items and higher scores indicated greater levels of stress. Reliability was low (α= 0.66) so results should be interpreted with caution.

> *Fatigue*: Each item began with the stem "*How often do you feel fatigued at work because of…..*" (e.g. "*…the working hours*"; 1 = Never to 5 = Always). Two non work related items ("*…young family members sleep patterns*" and "*…other issues/activities outside of work*") were removed to improve reliability (α= 0.90). The score was the mean of the two items and higher scores indicated greater fatigue.

> *General Health*: A variety of psychological health issues including insomnia, anxiety and depression was measured by twelve items on a scale from 1 = Not at all to 4 = Much more than usual (GHQ-12 – Goldberg & Williams, 1972). Participants were asked to respond with regard to their health over the three week period just prior to completing the questionnaire. Each item began with the stem "*Over the past few weeks to what extent have you….*" (e.g. "*…lost much sleep over worry*"). Six items were reverse coded (e.g. "*…been feeling reasonably happy, all things considered*"). The score was the mean of the twelve items and lower scores indicated better psychological health (α= 0.79).

Procedural Violations

Procedural violations were measured by nine items from the Violation Behaviour and Violation Attitude subscales of the MES Version 3 (Fogarty & Buikstra, 2008). Factor analysis revealed two factors that contained a mixture of items from the two original subscales and explained 52% of the variance (Appendix D). New factors were computed that fit the present data. These were:

> *Situational Violations – "Get the job done":* The perceived need to engage in violations in order to get the job done was measured by five items (e.g. "*Managers turn a blind eye to shortcuts/risk taking by supervisors if the flying program or task deadline is met*") on a scale ranging from 1 (Never) to 5 (Always). The score was the mean of the five items and higher scores indicated a greater perceived need to engage in violations in order to get the job done (α=0.74).

> *Routine Violations*: Willingness to defy rules and procedures was measured by four items (e.g. "*I will temporarily disconnect or remove a part to make a job easier, but not document the disconnection/removal*") on a scale ranging from 1 (Never) to 5 (Always). Two items were reverse coded ("*When given a task, I ensure the approved procedures are followed*"; "*Where I work, tasks are performed in accordance with maintenance policy, process and procedure*"). The score was the mean of the four items and higher scores indicated a greater inclination to break the rules. Reliability was low so results should be interpreted with caution (α=0.65).

Errors

Self reported errors were measured using the error types subscale from the MES Version 3 (Fogarty & Buikstra, 2008). The frequency with which errors (e.g. memory lapses, skill based errors) were made in the three months prior to the survey was measured by ten items (e.g. "*I have left a tool or some other item in an aircraft*"; "*I have installed a part the wrong way*") on a scale from 1 (Never) to 5 (Always). The score was the mean of the ten items (α=0.82). Higher scores indicated a greater incidence of errors.

Procedure

The first phase of this research project involved gaining approval to conduct psychological research in the RNZAF. The research was approved by the Chief of Air Force on 03 June 2010. Massey University Ethics Committee approval was obtained (MUHECN 10/042). Assurances were obtained from the RNZAF Web Manager that anonymity and confidentiality of raw data would be protected and from the Directorate of Air Force Safety and Health (DASH) that the research data would not become the subject of disciplinary action.

A paper version of the research questionnaire was drafted and piloted on Subject Matter Experts (SMEs), then revised and shortened so that it could be completed within approximately 15 minutes. New Zealand expressions were used in place of Australian terminology (e.g. black books) and the timeframes, instructions and response scales were all reviewed to ensure that they were meaningful and practical for use with this sample. The online questionnaire was developed on the secure RNZAF intranet site and trialled by SMEs who confirmed the most relevant ranks and units to be invited to participate in the study.

Information on the research project and the link to the information page and questionnaire were emailed to Maintenance Flight Commanders (MFCs) and the Commanding Officer of Maintenance Wing. On the 29th of July 2010, the researcher presented information on the research project to 5 Squadron, 6 Squadron and 40 Squadron at their weekly Maintenance brief. MFCs subsequently forwarded personnel an invitation email from the researcher with a link to the information page and questionnaire. Due to the fragmented nature of the units within Maintenance Wing, Maintenance Wing personnel received only the email through their command chain.

The questionnaire was accessible for approximately one month until the 31st of August 2010. The raw data was subsequently collated and analysed using SPSS (version 18). The summarised results were discussed with the Directorate of Psychology and DASH before being distributed to the units in an internal RNZAF report. The research results are presented in Chapter Five of this thesis.

Data Analysis.

Initial analysis

Principal Components Analysis (PCA) using Varimax rotation was conducted to determine the structure of the scales for EMC, EAC, Supervision, Psychological Health, Violations and Errors. All scales were suitable for factor analysis with Kaiser-Meyer-Olkin (KMO) statistics over 0.7 and Bartlett's test of Sphericity significant (Hair, Anderson, Tatham & Black, 1998). The number of factors chosen was based on Kaisers Stopping Rule and an analysis of the scree plot (Hair et al., 1998). Scale reliabilities were tested using Cronbach's alpha. c of Variance (ANOVAs) with Scheffe post-hoc comparisons were conducted to test differences between demographic groups.

Hypothesis testing

Bivariate correlations were measured using Pearson's r. Mediation was tested using Baron and Kenny's (1986) three step approach which requires the association between the independent and dependent variables to be established in the first step, the association between the independent variable and the mediator demonstrated in the second step and the mediation effect on the dependent variable demonstrated in the third step. A mediation effect indicates that the independent variable impacts on the mediator which in turn impacts on the dependent variable. Mediation is therefore evidence of an indirect relationship between independent and dependent variables through the mediator. The Medgraph application (Jose, 2003) on the Victoria University website (http://www.vuw.ac.nz) was utilised to compute Sobel's test of significance and the type of mediation, partial or full.

Chapter Five: Results

The means and standard deviations are presented in Table 4. Normality checks (skew and kurtosis) showed positive skewness on EAC: covering up errors, violations and errors as well as negative skewness on Supervision. These outcomes are to be expected in an aviation maintenance environment and as in Fogarty and Buikstra (2008) the degree of skewness was not judged to be problematic for multivariate analyses.

Sample Description.

Participants reported significantly higher levels of EMC than either of the two samples in Van Dyck et al., (2005), (Study 1 mean = 3.22, t_{188}=27.76, p<0.001; Study 2 mean = 3.43, t_{188}=19.94, p<0.001). Conversely, EAC was reported to be significantly lower than that of the 65 organisations sampled in Van Dyck et al. (2005)[9], (mean = 2.61 t_{188}=-4.34, p<0.001). Participants also reported significantly higher levels of supervision than the Australian Defence Force maintenance personnel sampled in either Fogarty (2004), (mean=3.46 t_{188}=9.03, p<0.001) or Fogarty (2005), (mean = 3.59, t_{188}=5.83, p<0.001). EAC: Error Strain had an average score almost twice that of EAC: Covering up Errors, yet both scales had high maximum scores at 5 and 3.83 respectively. Means for Psychological Health were in the mid range, with Stress and Fatigue scores demonstrating the most variability. A small amount of job related errors and violations were acknowledged by this sample. Further comparisons could not be made with either, Fogarty and Buikstra's (2008) or Fogarty's (2004; 2005) scores as scale means were not provided or, different measures or response scales were used.

[9] EAC was only assessed in the first study in Van Dyck et al., (2005)

Table 4: Summary Statistics (N=189)

	Mean	SD
EMC	3.97	.37
EAC	2.46	.48
EAC: Error Strain	3.24	.62
EAC: Covering Up Errors	1.81	.54
Supervision	3.83	.56
Stress	2.56	.67
Fatigue	2.31	1.05
GHQ	2.16	.38
Situational violations	2.06	.59
Routine violations	1.79	.53
Errors	1.55	.41

Participants were asked to provide examples of errors they had thought about while answering the EMC and EAC items (Table 5). Responses varied, with some providing descriptions of types of error while others identified causes of error.

Table 5: Examples of error information provided by participants

Types of error
Leaving a foreign object in an aircraft after completing a task
Foreign Object Damage (FOD)
Tool control errors
Incorrect use of tools
Incorrect tool used
Accidentally breaking or damaging a tool/equipment
Missing out a step in a maintenance task
Errors/faults missed during supervision checks
Documentation completed incorrectly or not completed
SAP errors
Incorrect fault diagnosis
Damage caused by unfamiliarity with either the task or equipment
Damage to aircraft/equipment or personal injury as a result of ignorance of correct procedure
Causes of error
Errors due to memory lapses
Errors due to not following procedures
Errors caused by leaving out steps in a task because they were ‘too hard’ or because ‘we always miss out this step’ or taking the ‘good enough’ approach.
Errors from poor trade skills/trade practices
Errors caused by improvising tooling or procedures when correct tool or material not available
Errors caused by not properly inspecting new parts to be fitted to an aircraft
Errors caused by a lack of situational awareness
Errors due to insufficient supervision
Errors caused by supervisors assuming subordinates training had covered something it had not
Errors due to rushing to meet taskings

Participants were also given the opportunity to provide general comments on the research. Responses provided clear examples of error management and error aversion climates. Examples of comments reflecting an error management climate (EMC) include:

> *"The Air Force has an open "no blame" culture in the maintenance technical areas and if the person making the mistake/error informs their supervisor at the earliest opportunity, frequently no further disciplinary action is carried out. Also, if an error has occurred during normal maintenance and discovered by inspection/supervision the error is pointed out to those on the task, evaluated, and the correct method is taught to those involved and the defect rectified. If we can all learn from these mistakes/errors it is bought up in the weekly meeting and/or monthly training day. It is highly discouraged to hide any mistakes and involves strict discipline if the error has been discovered to have been covered up".*

> *"Maintainers are generally forthcoming with errors they have made. There is an understanding that the airworthiness of the aircraft is the most important thing. Unless it is a case of negligence there is generally no 'serious' repercussions for having made an error. If there is a lesson to be learned in modifying the way we carry out a procedure that can prevent the same error in the future then it is brought to everyone's attention. If there is no specific lesson to be learned then everyone is reminded to be vigilant in their work".*

Examples of comments reflecting an EAC include:

> *"People are encouraged to be open about their mistakes and inform supervisors so proper remedial action/repair can be completed. In my experience the person then naively comes forward to report a mistake and is disciplined severely, they would be unlikely to ever admit a mistake again and would more likely try to camouflage their mistakes in future".*

> *"I am not aware of people being stressed about not making errors but there is an awareness that you don't want to be the person who makes an error. There is generally a bit of ribbing that goes on between maintainers if someone has made an error. This is not over the top but serves as a reminder to take care in your work so that you are not on the receiving end".*

Demographic Group Differences

Position

Four groups of participants took part in this study. The least qualified/most junior participants were Mechanics, followed in seniority by Technicians, then Junior Non Commissioned Officers (JNCOs) and, at the most senior level, Senior Non Commissioned Officers (SNCOs). EMC scores decreased as position increased and were significantly higher for Mechanics than for SNCOs ($F_{(3,184)} = 3.46$, $p<.05$, $eta^2 =.05$). Supervision scores also decreased with position and were significantly higher for Mechanics than for JNCOs and SNCOs ($F_{(3,184)} = 9.91$, $p<.01$, $eta^2 =.14$). Stress and Fatigue scores on the other hand increased with position and were significantly higher for SNCOs than for Mechanics (Stress $F_{(3,184)} = 3.93$, $p=.01$, $eta^2 =.06$; Fatigue $F_{(3,184)} = 3.19$, $p<.05$, $eta^2 =.05$). Finally, Situational violations were significantly higher for JNCOs and SNCOs than for Mechanics ($F_{(3,183)} = 7.30$, $p<.01$, $eta^2 =.11$).

Trade

The technical trades involved in this study were grouped into three trade groups: Aircraft Technicians, Avionics Technicians and Small Trades Technicians[10] (Armament, Safety & Surface and the Small Technical Trades). EAC: Error Strain scores were significantly higher for Aircraft Technicians than for Small Trades Technicians ($F_{(2,184)} = 4.46$, $p<.05$, $eta^2 =.05$). Supervision scores were significantly lower for Small Trades Technicians than for Aircraft and Avionics Technicians ($F_{(2,184)} = 6.31$, $p<.01$, $eta^2 =.06$). Similarly, Fatigue scores were significantly lower for Small Trades Technicians than for Aircraft and Avionics Technicians ($F_{(2,184)} = 12.93$, $p<.01$, $eta^2 =.12$).

Squadron

Fatigue scores were significantly higher for Force Element Groups (5 Squadron, 6 Squadron and 40 Squadron) than for the Maintenance Wing units (Maintenance Support Squadron & Avionics), ($F_{(4,180)} = 16.88$, $p<.01$, $eta^2 =.27$).

[10] These trades combined represented 30% of the Technical personnel on the units involved

Significant differences were found in Fatigue scores across all three demographic variables (position, trade, and squadron). These demographic variables alone predicted 28% of the variance in Fatigue scores (Table 6).

Table 6: Demographic Variables as Predictors of Fatigue

DV	IV	B	SEB	*β*	*Model R^2*	*Adj. R^2*	*Sig.*
Fatigue	Position	.335	.157	.137	.294	.282	.034
	Trade	-.378	.163	-.161			.021
	Squadron	-.902	.144	-.433			.000

Importantly, there were no significant differences in either routine violations or errors across position, trade or squadron.

Correlation Analysis

Better supervision was associated with higher levels of EMC, lower levels of EAC (less error strain and covering up errors), less stress, better general psychological health and, fewer errors and violations (Table 7). Supervision was not significantly correlated with fatigue. Higher levels of EMC were associated with better supervision and psychological health and lower levels of EAC, violations and errors. Higher levels of EAC were associated with more violations and errors, worse psychological health, poorer supervision and lower levels of EMC. Higher levels of self reported violations were associated with lower levels of EMC, higher levels of EAC, poorer supervision, worse psychological health and a greater frequency of errors. Neither EAC: error strain or stress were significantly associated with routine violations. Higher levels of self reported errors were associated with lower levels of EMC, higher levels of EAC, poorer supervision, greater stress and fatigue, and higher levels of violations. General psychological health and EAC: error strain were not significantly correlated with errors.

Table 7: Correlation Matrix

Scale	Correlations										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1. EMC	1										
2. EAC	-.392**	1									
3. EAC: Error Strain	-.165*	.830**	1								
4. EAC: Covering up Errors	-.484**	.845**	.404**	1							
5. Supervision	.499**	-.369**	-.191**	-.419**	1						
6. Psych. Health: Stress	-.267**	.325**	.308**	.235**	-.303**	1					
7. Psych. Health: Fatigue	-.198**	.198**	.196**	.143*	-.069	.406**	1				
8. Psych. Health: GHQ	-.191**	.202**	.192**	.148*	-.282**	.359**	.211**	1			
9. Violations: Situational	-.356**	.430**	.252**	.463**	-.312**	.350**	.159*	.335**	1		
10. Violations: Routine	-.304**	.205**	.079	.260**	-.174*	.122	.215**	.196**	.467*	1	
11. Errors	-.363**	.278**	.135	.327**	-.250**	.170*	.173*	.134	.385**	.525**	1

*0.05 Level of Significance **0.01 Level of Significance

Hypothesis Testing

All but one of the correlation hypotheses was supported. Hypotheses one through four were all supported: EMC was negatively correlated with EAC (H1); EMC was negatively correlated with errors (H2a) and EAC with positively correlated with errors (H2b); supervision was positively correlated with EMC (H3a) and negatively correlated with EAC (H3b); EMC was correlated with lower levels of psychological health (H4a) and EAC was correlated with higher levels of psychological health (H4b). Hypothesis five was partially supported, stress and fatigue were positively correlated with errors but the relationship between general psychological health and errors was not significant. Hypotheses seven and eight were supported: EMC was negatively correlated with violations (H7a) and EAC was positively correlated with violations (H7b); and finally errors and violations were positively correlated (H8).

Regression

Baron and Kenny's (1986) three step approach to mediated regression was utilised to test the mediation hypotheses. As there were significant demographic group differences the demographic variables were dummy coded for the regression as below:

Position:	0=Mechanic (non qualified Technicians)
	1=Technician, JNCO and SNCO (qualified Technicians)
Trade:	0=Aircraft Technician, Avionics Technician
	1=Small Trades
Squadron:	0= 5 Squadron, 6 Squadron and 40 Squadron (FEGs)
	1= Maintenance Support Squadron and Avionics (Maintenance Wing)

The dummy coded variables were entered first into the regression analysis when there were significant group differences in the independent, dependent or mediator variables involved. Demographic variables were dropped and the regression repeated without them if their effect was found to be non significant through all three steps of the model. Regressions were not conducted where there were non significant correlations between variables (e.g. GHQ and Errors).

Hypothesis 6 which proposed that Psychological Health (as measured by Stress, Fatigue and GHQ) would mediate the relationships between a) EMC, b) EAC and errors was not supported. Stress and fatigue did not mediate either relationship and there was no relationship between general psychological health (GHQ) and errors to mediate.

Support was found for Hypothesis 9a which proposed that violations would mediate the relationships between EMC and Errors. Analysis confirmed that violations partially mediated the relationships between EMC and Errors (Table 8). There was also support for Hypothesis 9b which proposed that violations would mediate the relationships between EAC and Errors (Table 9). However, of the two EAC subscales, only Covering up Errors was significantly correlated with Errors. Violations partially mediated the relationship between Covering up Errors and Errors (Table 10), but there was no relationship between Error Strain and Errors to mediate.

The pathways supported by the analysis are displayed in Figure 9.

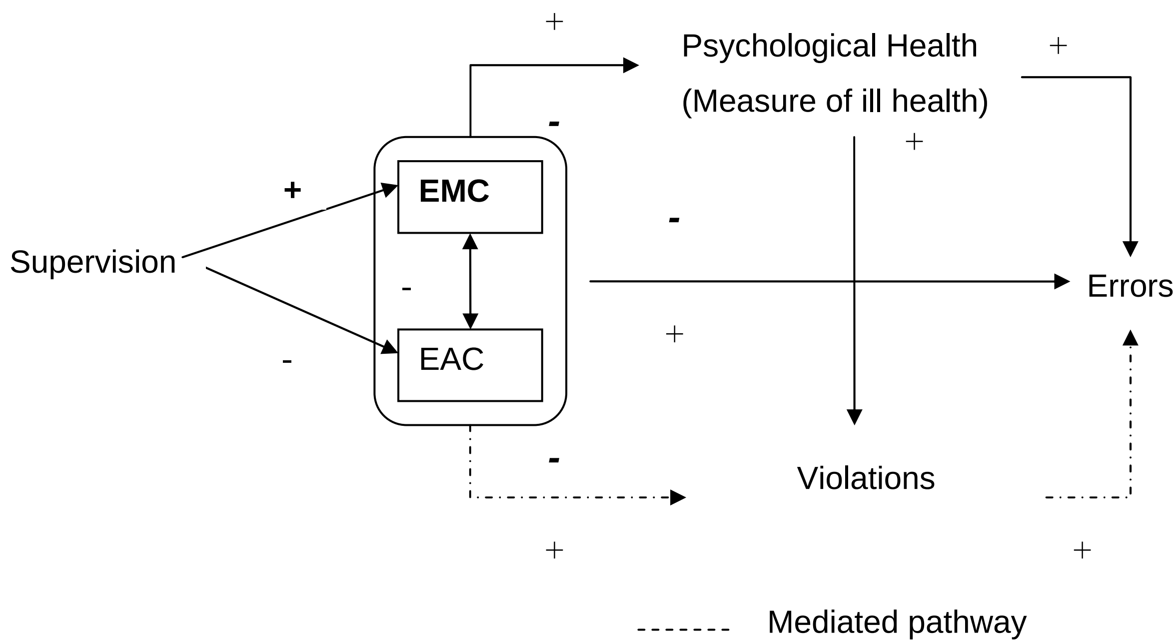

Figure 9: Revised Figure 8 showing supported pathways

Hypothesis 9a: Violations (as measured by Situational and Routine violations) will mediate the relationship between EMC and Errors.

Table 8: Violations as a Mediator of the Relationship between EMC and Errors

	DV	IV	B	SEB	*B*	*Model* R^2	*Adj.* R^2	*Sig*	*Sobel Test*
Situational violations									
Step 1	Errors	Position	-.110	.067	-.115	.140	.131	ns	-3.37 (p<0.001)
		EMC	-.415	.076	-.379			.000	
Step 2	Situational Violations	Position	.309	.096	.220	.174	.165	.001	
		EMC	-.507	.109	-.316			.000	
Step 3	Errors	Position	-.183	.065	.191	.237	.225	.005	
		EMC	-.296	.076	-.270			.000	
		Sit. Violations	.235	.048	.343			.000	
Routine violations									
Step 2	Routine Violations	Position	.037	.089	.030	.090	.080	ns	-3.56 (p<0.001)
		EMC	-.418	.102	-.293			.000	
Step 3	Errors	Position	-.124	.059	-.129	.332	.321	.037	
		EMC	-.267	.070	-.244			.000	
		Routine Violations	.353	.049	.459			.000	

Hypothesis 9b: Violations (as measured by Situational and Routine violations) will mediate the relationship between EAC and Errors.

Table 9: Violations as a Mediator of the Relationship between EAC and Errors

DV		IV	B	SEB	*B*	*Model* R^2	*Adj.* R^2	*Sig*	*Sobel Test*
Situational violations									
Step 1	Errors	Position	-.091	.069	-.095	.084	074	ns	3.80 (p<0.001)
		EAC	.242	.060	.291			.000	
		Errors	.296	.092	.211			.002	
Step 2	Situational Violations	Position				.228	.220	.000	
		EAC	.480	.080	.393				
Step 3	Errors	Position	-.166	.066	-.173	.191	.178	.013	
		EAC	.120	.061	.144			ns	
		Sit. Violation	.255	.052	.373			.000	
Routine violations									
Step 2	Routine Violations	Position	.064	.091	.051	.043	033	ns	2.51 (p=0.01)
		EAC	.209	.079	.193			.009	
Step 3	Errors	Position	-.115	.060	-.120	.315	.304	ns	
		EAC	.163	.053	.196			.002	
		Routine Violations	.378	.048	.492			.000	

Table 10: Violations as a Mediator of the Relationship between Covering up Errors and Errors

DV		IV	B	SEB	*β*	*Model R^2*	*Adj. R^2*	*Sig*	*Sobel Test*
Situational violations									
Step 1	Errors	Position	-.101	.068	-.105	.114	.105	ns	3.75 (p<0.001)
		Covering Up Errors	.255	.053	.340			.000	
Step 2	Situational Violations	Position	.285	.091	.203	.255	.242	.002	
		Covering up Errors	.469	.071	.428			.000	
Step 3	Errors	Position	-.168	.066	-.17	.203	.190	.012	
		Covering Up Errors	.144	.056	.192			.011	
		Sit. Violations	.237	.052	.346			.000	
Routine violations									
Step 2	Routine Violations	Position	.051	.090	.041	.067	.057	ns	3.15 (p=0.001)
		Covering Up Errors	.242	.070	.248			.001	
Step 3	Errors	Position	-.119	.059	-.124	.325	.314	.045	
		Covering Up Errors	.167	.048	.223			.001	
		Routine Violations	.365	.048	.475			.000	

Prediction of Errors

As the relationship between error climate and errors was not mediated by psychological health as expected, further analysis was conducted to determine if the addition of psychological health and violations improved prediction of errors over the variance accounted for by the organisational variables (EMC, EAC: Error Strain, EAC: Covering up Errors and Supervision) and position (Table 11). The regression analysis indicated that this model predicted over a third of errors, R^2=.370, $F_{(10, 177)}$ =10.382, p<.001. However, the analysis suggested that only routine violations and position were significant predictors of errors. Routine violations was the better predictor with a beta almost double that of position.

Table 11: Prediction of Errors

	B	β
Position	-.186**	-.194
EMC	-.143	-.131
EAC: Error Strain	.007	.011
EAC: Covering up Errors	.058	.078
Supervision	-.074	-.102
Stress	-.010	.016
Fatigue	.019	.049
GHQ	-.036	-.035
Situational Violations	.095	.139
Routine Violations	.300***	.390
F	10.382***	
Model R^2	.370	
Adj. R^2	.334	

*0.05 Level of Significance **0.01 Level of Significance ***0.001 Level of Significance

Prediction of Violations

Regression was also employed to determine if the addition of psychological health improved prediction of violations over that accounted for by the organisational variables and position.

Situational violations

The regression analysis suggested that this model predicted nearly half of the situational violations, R^2=.44, $F_{(9,178)}$ =15.79, p<.001 (Table 12). The specific variables identified as significant predictors were routine violations, EAC: covering up errors, stress, position and GHQ. Routine violations was again the best predictor and along with covering up errors had a much greater beta than that of the other predictors.

Table 12: Prediction of Situational violations

	B	β
Position	.209*	.148
EMC	-.070	-.044
EAC: Error Strain	.024	.026
EAC: Covering up Errors	.305***	.278
Supervision	.031	.030
Stress	.169**	.191
Fatigue	-.053	-.093
GHQ	.220*	.144
Routine Violations	.385***	.342
F	15.785***	
Model R^2	.444	
Adj. R^2	.416	

*0.05 Level of Significance **0.01 Level of Significance ***0.001 Level of Significance

Routine violations

The regression analysis suggested that this model predicted a quarter of routine violations, R^2=.28, $F_{(9,178)}$ =7.56, p<.001 (Table 13). Situational violations and fatigue significantly contributed to the prediction of routine violations. Situational violations was the best predictor with a beta more than twice that of fatigue.

Table 13: Prediction of Routine violations

	B	β
Position	-.093	-.074
EMC	-.211	-.148
Error Strain	-.048	-.057
Covering up Errors	.012	.013
Supervision	-.003	-.003
Stress	-.109	-.139
Fatigue	.088*	.175
GHQ	.074	.054
Situational Violations	.396***	.445
F	7.561***	
Model R^2	.277	
Adj. R^2	.240	

*0.05 Level of Significance **0.01 Level of Significance ***0.001 Level of Significance

Participants responding to an open ended survey question regarding this research project provided a number of comments regarding violations. Examples include:

> *"It has long been known short cuts are used to achieve the flying program."*

> *"Current books document a full checkout but yet often only part of it is required due to the maintenance carried out. Therefore I would often not follow the procedure to the letter, but am confident my knowledge and training allows to distinguish what parts of the testing is required"*

> *"Often aircraft manuals are not correct, which leads technicians to deviate from the manual (follow best practices). In most cases this is done in conjunction with senior managers and/or engineering staff".*

> *"The books need to be trusted and if there's stuff in there that isn't necessary, eventually we'll end up deciding for ourselves what to follow and what to ignore."*

Chapter Six: Discussion

This research project examined the role of error climate in aviation maintenance performance. The error climate of the Technical Trades in the Royal New Zealand Air Force (RNZAF) was assessed through self report questionnaire and determined to be a good error climate.

As expected, EMC was negatively correlated with EAC. This is consistent with the theory put forward in Van Dyck et al., (2005). Compared to data from the 65 organisations that took part in Van Dyck et al's study, the present study found higher levels of EMC and lower levels of EAC, suggesting that error climate is particularly important in safety environments and that a strong EMC and a weak EAC are necessary for safety.

Two subscales of EAC were identified: covering up errors and error strain. Error strain may reflect a strong commitment to high performance as well as the negative reactions of supervisors to errors while covering up errors may reflect a punitive environment or factors related to organisational constraints such as job insecurity (Rybowiak et al., 1999; Van Dyck et al., 2005). Covering up errors, but not error strain, was related to errors and routine violations. This suggests the need for further research into the facets of EAC and their correlates.

EMC was negatively related to self-reported error rates, while EAC was positively related to error rates. This supports the theory that non punitive climates which support the open analysis and discussion of error and emphasise learning from error can lead to secondary error prevention through learning (Van Dyck et al., 2005). In contrast, climates characterised by strain and fear of committing or reporting errors can increase the likelihood of error, inhibit discussion of and learning from errors and make secondary error prevention less likely. These results are consistent with that of previous research (e.g. Edmondson, 1999; Hoffman & Mark, 2006).

In line with previous research by Edmondson (1999) and, Hoffman and Mark (2006), high quality supervision was positively related to EMC. In the present study, correlations with stress, GHQ and error strain were higher for supervision than for EMC. Better supervision was also related to fewer errors and violations, supporting the idea that supervision is a key factor in safety climate, safety outcomes and the psychological health of the workgroup.

Error climate was related to all of the psychological health variables. EAC was related to increased stress and fatigue, and poorer general psychological health while the opposite relationship was found for EMC.

EMC was negatively related to violations, consistent with findings by Cigularov et al. (2010). EAC was positively related to violations in the current study but was not studied in Cigularov et al., (2010). Fogarty (2005b) asserts that the link between safety climate and violations indicates that violations occur regardless of whether the individual wishes to commit them. Technicians have endorsed this view in focus groups where they claimed that organisational factors such as resource constraints, unworkable procedures and unrealistic deadlines compelled them to commit violations (McDonald, Corrigan, Daly & Cromie, 2000). The results in the current study provide further evidence that an EMC with open discussion, participative problem solving and learning can identify and tackle issues early, so that individuals are not compelled to commit violations and can also develop workable safety protocols that workers accept and comply with. The opposite appears to be true of an EAC.

Errors and violations were positively related. Violations are often a precursor of error, although workers commonly believe that they have the skills and the knowledge to carry out a violation without error (Fogarty & Buikstra, 2008; Helmreich, 2000; McDonald et al., 2000; Reason & Hobbs, 2003).

In the present study, the role of violations as mediators between error climate and errors, and the finding that routine violations were the strongest predictor of errors, indicates that violations lead to errors, and that organisational and workgroup factors which play a significant role in violations can have an indirect impact on error. However the mediation by violations was only partial, suggesting that error climate also has a direct relationship with error. This may represent the mitigation (EMC) or compounding (EAC) of negative reactions to error by error climate.

Routine violations were the best predictors of errors, consistent with Helmreich's (2000) finding that individuals who commit violations also commit more errors. Routine violations represent rule defiance and are often the product of poor procedures (Reason & Hobbs, 2003). Individuals who break the rules by not following procedure may do so because the procedures are out of date or ill suited to the situation. Errors are then more likely to occur as workers are operating without well established procedures and may be unaware of the implications of rule departures.

The significant predictors of situational violations from strongest to weakest were routine violations, covering up errors, stress, position and GHQ. The finding that routine violations were the strongest predictor demonstrates that the more violations are committed the more it becomes the norm to commit violations and the more violations (of all types) are committed (Lawton, 1998). The covering up errors scale of EAC was the second best predictor of situational violations. This may indicate that individuals commit violations in order to cover up errors or that those who cover up errors also commit more violations. Safety researchers have recognised the importance of revealing and learning from errors, and the aviation industry has adopted blame free voluntary reporting systems as a result. The need to reveal errors is also recognised in the healthcare industry, although there is still the tendency to cover up errors in healthcare which may account for the relatively high error rate in healthcare (Hughes et al., 2009). The finding that covering up errors was the only climate factor that predicted violations highlights the importance of this variable.

Position also predicted situational violations. JNCOs and SNCOs had higher rates of situational violations than mechanics, perhaps because more senior technicians are more often in situations that compel them to make situational violations due to resource constraints, as suggested by some of the qualitative data which described a lack of SNCOs.

Furthermore, as mechanics are all still under training they are less likely to risk committing a situational violation or be in a position where they might be compelled to do so.

The other significant predictors of situational violations were stress and general psychological health, indicating that individuals whose psychological health has been compromised may be more likely to take shortcuts. The findings suggest that error climate was related to individual psychological health which in turn was related to both errors and situational violations. It is possible that psychological health may mediate the relationships between error climate and situational violations. However, previous research of a similar nature (e.g. Fogarty & Buikstra, 2008; Oliver et al., 2002) did not suggest such a relationship. Further research is needed to explore this possibility.

There were only two significant predictors for routine violations: situational violations and fatigue. As with situational violations this demonstrates that the more individuals commit one type of violation the more likely they are to commit other types. It is possible that when situational factors act to increase the rates of situational violations, individuals come to have less regard for the rules and become more likely to commit routine violations. Fatigue may also cause individuals to take shortcuts, for example using informal procedures or 'cheat sheets' rather than referring to manuals. Further research is needed to clarify these possibilities.

Unexpectedly, psychological health did not mediate the relationship between error climate and errors. Psychological health variables were not significant predictors of errors, although they predicted violations. These results contradict other research which emphasises the role of psychological health as well as organisational factors in the production of error (e.g. Fogarty 2004; 2005; Fogarty & Buikstra, 2008). The psychological health measures in the present study had relatively low internal consistency reliabilities and results should be treated with caution. However fatigue and stress were positively related to error, in line with previous research. More reliable measures may be more likely to reveal the expected and well documented effects of stress and fatigue on error. Although the GHQ-12 is a well utilised measure of general psychological health, it was not significantly related to errors in the current study. Further research is needed into the associations between psychological health variables and error.

Implications of the Findings

This study appears to be the first to examine error climate in the aviation industry and also the first to examine error climate constructs in a safety context. Most of the initial research in this area has only assessed components of error climate (e.g. Hoffman & Mark, 2006; Hughes et al., 2009) or EMC (e.g. Cigularov et al., 2010). Both EMC and EAC appear to be important in safety as both had significant relationships with errors and violations, and both should be included in future research involving errors and safety.

This study also appears to be the first to provide evidence of the expected negative relationship between EMC and EAC. This suggests that a strong EMC and a weak EAC, as found in the current study, are necessary for safety. It also demonstrates that EMC, which acknowledges the occurrence of error and develops processes to deal with error, does not invite additional error but serves a valuable function, as suggested by Van Dyck et al. (2005), in reducing errors and violations.

A further implication is that safety-focused organisations may have skills in learning from errors that others could benefit from. Units or organisations with poor error climates may be able to improve their management of error by studying those who excel in this area. This may be an attractive and important implication for any organisation given that Van Dyck et al. (2005) demonstrated a positive link between EMC and organisational performance.

Error climate also impacts on violations which in turn impact on errors. This emphasises the need for organisations to distinguish between errors and violations, and reinforces the idea that violations are symptoms of organisational problems rather than the product of problematic individuals. Organisations intent on reducing error should focus on improving the organisational factors that lead to violations. In this study, the relevant organisational factors were error climate and supervision. Although error climate and supervision scores were high and the rates of self-reported errors and violations were low, survey comments indicated that violations could be reduced by improving traditional safety climate factors such as policies and procedures. The organisation may benefit from conducting safety climate research to identify the organisational factors that are contributing to violations, and from working with technicians to develop relevant policies and procedures. This requires the organisation to see technicians as part of the solution rather than the problem and to ensure error and safety climates support the opportunity to identify underlying issues affecting violations. This is consistent with a strong EMC and is likely to be important in this situation.

The study highlighted that the aviation industry in particular has much to gain from this type of research. While the aviation industry has a long history of human factors research there is a lack of climate research in aviation, which could provide empirical evidence of organisational precursors to unsafe acts, errors and violations (Fogarty, 2004; Fogarty & Buikstra, 2008). From an organisational perspective, climate research can uncover latent errors before they are implicated in an adverse event. There is evidence to suggest that organisations need to assess their own particular situations if they are to develop successful interventions, as error climate can vary significantly across organisations (Helmreich, 2000). The Royal New Zealand Air Force would benefit from continuing and extending this type of research within their organisation.

Limitations of this Study

A limitation of this study is the use of self report data for all measures which opens up the possibility of common method bias and socially desirable responding. Although single source self-report data is the norm in safety research (Christian et al., 2009), the possibility that self reported errors and violations may not correlate with actual errors and violations must be acknowledged. While it would have been preferable to use actual data, confidentiality issues mean that this data could not be linked to individual perceptions of error climate. Future research that can address these limitations would be valuable.

Another limitation is the low response rate of 36%. This is below that of Fogarty (2004; 2005) and, Fogarty and Buikstra (2008) but it is reflective of voluntary questionnaires and it is higher than that achieved in many published papers (e.g. Cigularov et al., 2010; Gibbons et al., 2006; Van Dyck et al., 2005). Nevertheless, it is possible that this sample is not representative in that responses may only have been received from individuals who had committed fewer errors and violations or who were more willing to admit to them. Non response bias is therefore a possible factor in this study. It is also possible that the negative wording of some questions may have been off-putting to some participants. Future surveys can reframe measures in a more positive way, for example, covering up errors could become 'willingness to report errors' and safety compliance could be studied rather than violations, as is the norm in a lot of safety climate research (Clarke, 2006; Hoffman & Mark, 2006).

A final limitation is that the participants in this study were all from one military organisation which may limit the generalisability of these results. These results may be most applicable to military organisations, maintenance organisations, organisations within the aviation industry or high reliability organisations where serious safety hazards are a constant concern. The results may not generalise to organisations outside this group. Extending this study to other organisations will help to establish the generalisability of the findings.

Directions for future research

Future research should continue to examine the role of error climate in safety. Initial indications are that error climate will be an important organisational variable in safety. However, given the newness of this construct there is little empirical evidence to demonstrate this. A suitable progression for error climate in safety research may be through the use of the composite safety climate measure developed by Hoffman and Mark (2006). Alternatively, it may be prudent for future research to develop and validate a new composite measure that initially includes all of the components of error climate identified in Van Dyck et al., (2005). This measure could be used to further examine the role of organisational and individual variables in safety performance.

The present study included only three organisational variables: EMC, EAC and supervision. Further research can extend this to include other safety climate factors such as management commitment to safety, priority of safety over production and time pressure, which have demonstrated links to errors and violations. Another factor worth exploring is hierarchical position in the organisation, as initial indications suggested a trend for EMC perceptions to decrease as hierarchical position increased. Models can be developed to assist in explaining the occurrence of unsafe acts, which can then be tested on actual rates of errors and violations (Fogarty, 2005). Studies that examine the relationship between error climate and consequences of errors and violations such as incidents and accidents are also important given that error climate is likely to have a bigger impact on error consequences than on errors themselves (Van Dyck, 2008). Longitudinal research, along the lines of that conducted by Neal and Griffin (2006) for safety climate, can identify whether error climate has lasting and lagged effects on outcomes. Future research may also examine the pervasiveness of error climate as an organisational characteristic by comparing error climate perceptions across a cross section of units and hierarchical positions within organisations.

Conclusion

This study revealed that the effect of error climate on errors was partly mediated by violations. This result is consistent with that found for safety climate factors, which unlike error climate, are well established as precursors of unsafe acts. These findings suggest that error climate is an important organisational factor in safety, and aviation maintenance performance that warrants further examination. This research could assist aviation maintenance organisations to reduce aviation maintenance error and violations as well as improve efficiency in the maintenance environment. This research could also assist other organisations concerned with safety to reduce the occurrence of and improve the handling of unsafe acts.

References:

Alper, S.J., & Karsh, B.-T. (2009). A systematic review of safety violations in industry. *Accident Analysis and Prevention, 41*, 739-754.

Bandura, A. (1986). *Social Foundation of Thought and Action*: A Social Cognitive Theory, Prentice Hall, Englewood Cliffs, NJ.

Baron, R.M., & Kenny, D.A. (1986). The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51*(6), 1173-1182.

Battmann, W. & Klumb, P. (1993). Behavioural economics and compliance with safety regulations, *Safety Science, 16*, 35-46.

Bauer, J. & Mulder, R.H. (2007). Modelling learning from errors in daily work. *Learning in Health and Social Care, 6*(3), 121-133.

Carr, J.Z., Schmidt, A.M., Ford, J.K., & DeShon, R.P. (2003). Climate perceptions matter: A meta-analytic path analysis relating molar climate, cognitive and affective states, and individual level work outcomes. *Journal of Applied Psychology, 88*, 605-619.

Christian, M.S., Bradley, J.C., Wallace, J.C., Burke, M.J. (2009). Workplace Safety: A Meta-Analysis of the Roles of Person and Situation Factors. *Journal of Applied Psychology, 94*(5), 1103-1127.

Cigularov, K.P., Chen, P.Y., & Rosecrance, J. (2010). The effects of error management climate and safety communication on safety: A multi-level study. *Accident Analysis and Prevention, 42*, 1498-1506.

Clarke, S. (2006). The relationship between safety climate and safety performance: A meta-analytic Review. *Journal of Occupational Health Psychology, 11* (4), 315-327.

Cropanzano, R. & Wright, T. A. (2001). When a "Happy" Worker is really a "Productive" Worker: A review and further refinement of the Happy-Productive Worker thesis. *Consulting Psychology Journal: Practice and Research, 53*(3), 182-199.

Cox, S.J. & Cheyne, A.J.T. (2000). Assessing safety culture in offshore environments. *Safety Science, 34*, 111-129.

Denison, D.R. (1996). What is the difference between organizational culture and organisational climate? A native's point of view on a decade of paradigm wars. *Academy of Management Review, 21*, 619-654.

De Witte, K., & van Muijen, J.J. (1999). Organizational culture: Critical questions for researchers and practitioners. *European Journal of Work and Organizational Psychology, 8*(4), 583-595.

Edmondson, A.C. (1996). Learning from mistakes is easier said that done: Group and organisational influences on the detection and correction of human error. The *Journal of Applied Behavioural Science, 32*, 5-28.

Ek, A., & Akselsson, R. (2007). Aviation on the ground: Safety culture in a ground handling company. *The International Journal of Aviation Psychology, 17*(1), 59-76.

Espin, S., Lingard, L., Baker, G.R., & Regehr, G. (2006). Persistence of unsafe practice in everyday work: an exploration of organizational and psychological factors constraining safety in the operating room. *Quality & Safety in Health Care, 15*, 165-170.

Fischer, M.A., Mazor, K.M., Baril, J., Alper, E., DeMarco, D. & Pugnaire, M. (2006). Learning from mistakes: Factors that influence how students and residents learn from medical errors.

Fleishman, E.A. (1953). Leadership climate, human relations training, and supervisory behaviour. *Personnel Psychology, 6*, 205-222.

Flin, R., Mearns, K., O'Connor, R., & Bryden, R. (2000). Measuring safety climate: Identifying the common features. *Safety Science, 34*, 177-192.

Fogarty, G. (2004). The role of organizational and individual differences variables in aircraft maintenance performance. *International Journal of Applied Aviation Studies, 4*(3), 73-90.

Fogarty, G. (2005). Psychological strain mediates the impact of safety climate on maintenance errors. *International Journal of Applied Aviation Studies, 5*(1), 53-63.

Fogarty, G.J., & Buikstra, E. (2008). A test of direct and indirect pathways linking safety climate, psychological health, and unsafe behaviours.

Fogarty, G.J. & Shaw, A. (2009). Safety climate and the theory of planned behaviour: Towards the prediction of unsafe behaviour. Accident Analysis and Prevention,

Frankel, A.S., Leonard, M.W. & Denham, C.R. (2006). Fair and just culture, team behaviour, and leadership engagement: The tools to achieve high reliability. *Health Services Research, 41*(4), 1690-1709.

Frederiksen, N., Jensen. O., & Beaton, A.E. (1972). *Prediction of organizational behaviour*. Elmsford, NY: Pergamon.

Frese, M. & Altmann, A. (1989). *The treatment of errors in learning and training*. In Bainbridge L, Ruiz Quintanilla A (Eds.), Developing skills with information technology (pp.65-86). Chichester, U.K.: Wiley.

Gibbons, A.M., von Thaden, T.L., Wiegmann, D.A. (2006). Development and initial validation of a survey for assessing safety culture within commercial flight operations. *The International Journal of Aviation Psychology, 16*(2), 215-238.

Glick, W.H. (1985). Conceptualizing and measuring organizational and psychological climate: Pitfalls in multilevel research. *Academy of Management Review, 10*(3), 601-616.

Goldberg, D.P. The detection of psychiatric illness by questionnaire. Oxford: Oxford University Press: 1972.

Guldenmund, F.W. (2000). The nature of safety culture: A review of theory and research. *Safety Science, 34*, 215-257.

Haddon-Cave (2009). The Nimrod Review. The stationery office: London.

Hair Jr., J.F., Anderson, R.E., Tahtam, R.L., & Black, W.C. (1998). Multivariate Data Analysis (5^{th} ed.). Upper Saddle River, NJ: Prentice-Hall.

Heimbeck, D. Frese, M., Sonnentag, S., & Keith, N. (2003). Integrating errors into the training process: The function of error management instructions and the role of goal orientation. *Personnel Psychology, 56*, 333-361.

Helmreich, R.L. (2000). On error management: Lessons from aviation. *British Medical Journal, 320*, 781-785.

Helmreich, R.L. (2000). Culture, threat and error: Assessing system safety. Safety in Aviation: The Management Commitment: Proceedings of a Conference. London: Royal Aeronautical Society.

Helmreich, R.L., & Davies, J.M. (2004). Culture, threat and error: Lessons from aviation. *Canadian Journal of Anaesthesia, 51*, 333-361.

Helmreich, R.L., & Foushee, H.C. (1993). *Why crew resource management*? Empirical and theoretical bases of human factors training in aviation. In E.L. Wiener, B.G. Kanki, & R.L. Helmreich (Eds.), Cockpit resource management, (pp, 3-45). San Diego, CA: Academic Press.

Hobbs, A., & Williamson, A. (2002). Unsafe acts and unsafe outcomes in aircraft maintenance. *Ergonomics, 45*(12), 866-882

Hobbs, A., & Williamson, A. (2003). Associations between errors and contributing factors in aircraft maintenance. *Human Factors, 45*(2), 186-201.

Hobbs, A. (2004). Latent Failures in the hangar: Uncovering organizational deficiencies in maintenance operations. International Society of Air Safety Investigators Annual Seminar, 1 September 2004. Gold Coast Australia.

Hockey, R. (1996). Skilled performance and mental workload. In Warr P (Ed.). *Psychology at work* (4^{th} ed., pp. 13-39). London: Penguin.

Hofmann, D.A., & Mark, B. (2006). An investigation of the relationship between safety climate and medication errors as well as other nurse and patient outcomes. *Personnel Psychology, 59*, 847-869.

Hughes, L.C., Chang, Y., & Mark, B.A. (2009). Quality and strength of patient safety climate on medical-surgical units. *Healthcare Management Review*, January-March, 19-27.

Keith, N., & Frese, M. (2008). Effectiveness of error management training: A meta-analysis. *Journal of Applied Psychology, 93*, 59-69.

James, L.R., Choi, C.C., Ko, C.-H.E., McNeil, P.K., Minton, M.K., Wright, M.A., Kim, K.-I. (2008). Organizational and psychological climate: A review of theory and research. *European Journal of Work and Organizational Psychology, 17*(1), 5-32.

Kath, L.M., Marks, K.M. & Ranney, J. (2010). Safety climate dimension, leader-member exchange, and organizational support as predictors of upward safety communication in a sample of rail industry workers. *Safety Science, 48*, 643-650.

Keith, N. & Frese, M. (2008). Effectiveness of error management training: A meta-analysis. *Journal of Applied Psychology, 93*(1), 59-69.

Keyes, C.L.M., Shmotkin, D. and Ryff, C. D. (2002). Optimizing well-being: The empirical encounter of two traditions. *Journal of Personality and Social Psychology, 82*(6), 1007-1022.

Kontogiannis, T. (1999). User strategies in recovering from errors in man-machine systems. *Safety Science, 32*, 49-68.

Lawton, R. (1998). Not working to rule: Understanding procedural violations at work. *Safety Science, 28*, 77-95.

Lazarus, R. S. (1984). *Stress, Appraisal and Coping*. NY: Springer.

Litwin, G.H. & Stringer, R.A., Jr. *Motivation and organizational climate.* Boston: Division of Research, Harvard Business School, 1968.

LoBello, S.G. (1995). In Conoley, J.C., & Impara, J.S. (Eds.). The twelfth mental measurements yearbook. Lincoln, NE: Buros Institute of Mental Measurements.

Maurino, D.E., Reason, J., Johnston, N. & Lee, R.B. (1995). Beyond aviation human factors. Hants, England: Ashgate.

May, J.F. & Baldwin, C.L. (2009). Driver fatigue: The importance of identifying causal factors of fatigue when considering detection and countermeasure technologies. *Transportation Research, 12*, 218-224.

Michielsen, H.J., De Vries, J., & Van Heck, G.L. (2003). Psychometric qualities of a brief self rated fatigue measure: The fatigue assessment scale. *Journal of Psychosomatic Research, 54*, 345-352.

McDonald, N., Corrigan, S., Cromie, S., & Daly, C. (2000). Safety management systems and safety culture in aircraft maintenance organisations. *Safety Science, 34*, 151-176.

Naevestad, T.-O. (2009). Mapping Research on Culture and Safety in High-Risk Organisations: Arguments for a Socio-technical Understanding of Safety Culture. *Journal of Contingencies and Crisis Management, 7*(2), 126-136.

Naikar, N. & Saunders, A. (2003). Crossing the boundaries of safe operation: An approach for training technical skills in error management. *Cognitive Technology Work, 5*, 171-180.

Neal, A. & Griffin, M.A. (2000). The impact of organizational climate on safety climate and individual behavior. *Safety Science, 34*, 99-109.

Neal, A. & Griffin, M.A. (2006). A study of the lagged relationships among safety climate, safety motivation safety behavior, and accidents at the individual and group levels. *Journal of Applied Psychology, 91*, 946-953.

Neal, A., Griffin, M.A., & Hart, R.M. (2000). The impact of organizational climate on safety climate and individual behaviour. *Safety Science, 34*, 99-109.

Neitzel, R.L., Seixas, N.S., Harris, M.J., & Camp, J. (2008). Exposure to fall hazards and safety climate in the aircraft maintenance industry. *Journal of Safety Research, 39*, 391-402.

Norman, D.A. (1988). *The Psychology of Everyday Things*. Basic Books, New York.

Oliver, A., Cheyne, A., Tomas, J.M., & Cox, S. (2002). The effects of organizational and individual factors on occupational accidents. *Journal of Occupational and Organizational Psychology, 75*, 473-488.

Ostroff, C. (1993). The effects of climate and personal influences on individual behaviour and attitudes in organizations. *Organizational Behavior and Human Decision Processes, 56*, 56-90.

Öz, B., ÖzKan, T., Lajunen, T. (2010). An investigation of the relationship between organizational climate and professional drivers' driver behaviour. *Safety Science, 48*, 1484-1489.

Parker, C.P., Baltes, B. B., Young, S.A., Huff, J. W., Altmann, R.A., Lacost, H. A., & Roberts, J.E. (2003). Relationships between psychological climate perceptions and work outcomes: A meta-analytic review. *Journal of Organizational Behavior, 24*, 389-416.

Parke, B. & Kanki, B.G. (2008). Best practices in shift turnovers: Implications for reducing aviation maintenance turnover errors as revealed in ASRS reports. *The International Journal of Aviation Psychology, 18*(1), 72-85.

Perrow, C. (1984). *Normal accidents: Living with high-risk technologies*. New York: Basic Books.

Reason, J. (1990). *Human Error*. Cambridge: Cambridge University Press.

Reason, J. (1997). *Managing the risks of organizational accidents*. Hampshire, UK: Ashgate.

Reason, J., & Hobbs, A. (2003). Managing Maintenance Error: A practical guide. Surrey: Ashgate Publishing Limited.

Reason, J., Manstead, A., Stradling, S.l, Baxter, J., Campbell, K. (1988). Errors and violations on the roads. *Ergonomics, 33*, 1315-1332.

Rybowiak, V., Garst H., Frese M., Batinic, B. (1999). Error orientation questionnaire (EOQ): Reliability, validity, and different language equivalence. *Journal of Organizational Behavior, 20*, 527-547.

Schein, E.H. (1990). Organisational Culture. *American Psychologist, 45*(2), 109-119.

Schneider, B. (1975). Organizational climates: An essay. *Personnel Psychology, 28*, 447-479.

Schneider, B. (2000). The psychological life of organisations. In N.M. Ashkanasy, C.P.M. Wilderom, & M.F. Peterson (Eds.), *Handbook of organizational culture and climate*. Thousand Oaks, CA: Sage.

Schenider, B., Ehrhart, M.G. & Macey, W.H. (2011). Perspectives on organizational climate and culture. In Zedeck, Sheldon [Ed]. APA handbook of industrial and organizational psychology, Vol 1, (pp. 373-414). Washington, DC, US: American Psychological Association: US.

Seashore, S.E. and Bowers, D.G. (1970). Durability of organization change. *American Psychologist, 54*, 227-233.

Seo, D-C., Torabi, M. R., Blair, E. H., & Ellis, N.T. (2004). A cross-validation of safety climate scale using confirmatory factor analytic approach. *Journal of Safety Research, 35*, 427-445.

Sexton, J.B., Thomas, E.J. & Helmreich, R.L. (2000). Error, stress, and teamwork in medicine and aviation: cross sectional surveys. *British Medical Journal, 320*, 745-749.

Silva, S., Lima, M.L., Baptista, C. (2004). OSCI: an organisational and safety climate inventory. *Safety Science, 42*, 205-220.

Simard, M., & Marchand, A. (1997). Workgroups' propensity to comply with safety rules: the influence of micro-macro organisational factors. *Ergonomics, 40*(2), 172-188.

Stanton, N. A., & Salmon, P.M. (2009). Human error taxonomies applied to driving: A generic driver error taxonomy and its implications for intelligent transport systems. *Safety Science, 47*, 227-237.

Sussman, D. & Coplen, M. (2000). Fatigue and alertness in the United States railroad industry part I: the nature of the problem. *Transportation Research, 3*, 211-220.

Tagiuri, R. The concepts of organizational climate. In R. Tagiuri and G. Litwin (Eds.), *Organizational climate: Explorations of a concept*. Boston: Division of Research, Harvard Business School, 1968.

Taylor, J.C., & Thomas III, R.L. (2003). Toward measuring safety culture in aviation maintenance: The structure of trust and professionalism. *The International Journal of Aviation Psychology, 13*(4), 321-343.

Van Dyck, C., Frese, M., Baer, M., & Sonnentag, S. (2005). Organizational error management culture and its impact on performance: A two study replication. *Journal of Applied Psychology, 90*, 1228-1240.

Van Dyck, C. (2008). The tragic 1996 Everest expedition: a tale of error culture. *Netherlands Journal of Psychology, 65*, 22-34.

Wiegmann, D.A., & Shappell, S.A. (2001). Human error perspectives in aviation. *The International Journal of Aviation Psychology, 11*(4), 341-357.

Wiegmann, D.A., Zhang, H., von Thaden, T.L., Sharma, G., & Gibbons, A.M. (2004). Safety culture: An integrative review. *The International Journal of Aviation Psychology, 14*(2), 117-134.

Wright, T.A., Bonett, D.G., & Sweeney, D.A. (1993). Mental health and work performance: Results of a longitudinal field study. *Journal of Occupational and Organizational Psychology, 66*, 277-284.

Zohar, D. (1980). Safety climate in industrial organisations: Theoretical and applied implications. *Journal of Applied Psychology, 65*, 96-102.

Zohar, D. (2008). Safety climate and beyond: A multi-level multi-climate framework. *Journal of Applied Psychology, 65*, 96-102.

Zohar, D., & Luria, G. (2004). Climate as a social-cognitive construction of supervisory safety practices: Scripts as proxy of behaviour patterns. *Journal of Applied Psychology, 90*, 616-628.

Zohar, D., & Luria, G. (2005). A multilevel model of safety climate: Cross-level relationships between organization and group-level climates. *Journal of Applied Psychology, 90*, 616-628.

Appendices

Appendix A: Organisational description

The RNZAF is responsible for providing a military air capability that meets the security and defence requirements of the New Zealand government. RNZAF tasks which include transport of military personnel, search and rescue, disaster relief and maritime surveillance of New Zealand and Pacific waters are determined by the New Zealand Defence Force (NZDF) and are achieved through the Force Element Groups (FEGs).

The FEGs constitute the four operational squadrons (units) within the RNZAF – 3 Squadron (Helicopters), 5 Squadron (Maritime), 6 Squadron (Naval Support Helicopters) and 40 Squadron (Transport). Each squadron has its own maintenance unit to perform Operating Level Maintenance (OLM – 1st level maintenance) which is maintenance work that is generally limited to that directly on the unit's aircraft and systems to prepare the aircraft for operational requirements. Typical OLM tasks include: "*pre and post flight dispatch and receipt servicings; in situ operating checks, adjustments and alignments; simple rectification through replacement of Line Replaceable Units; fuelling and lubrication*" (NZAP 6000 Part 2 C1.2). Maintenance work on the FEGs is generally organised into two shifts, 7.45am – 4.30pm and an evening shift starting at 4pm and finishing after the last flight that evening. Maintenance personnel on these units work to a fairly high operational tempo and often deploy with the unit on exercise or operations within New Zealand and overseas.

Maintenance personnel working within Maintenance Wing on the other hand perform Intermediate Level Maintenance (ILM – 2nd level maintenance), providing aeronautical component repair as well as engineering and maintenance support to the FEGs and Base. Typical ILM tasks include: "*Bay servicing of components; minor repairs, rectifications, manufacture and modifications; calibration and alignment; bench checks and engine changes*" (NZAP 6000 Part 2 C1.2). Work within Maintenance Wing is usually carried out between 7.45am and 4.30pm with personnel utilising specialist test equipment and tooling to perform a broader range of maintenance tasks than that carried out on the FEGs. As a result, a wider variety of Technical Trades are represented on Maintenance Wing than on the FEGs.

RNZAF technical personnel working outside of the FEGs and Maintenance Wing generally work in units that do not carry out practical maintenance activities such as the Directorate of Aeronautical Configuration whose responsibilities include technical policy and standards. Technical personnel will however, work in a variety of these units over the course of their careers.

Rank Structure

RNZAF Rank Structure: Airmen/Airwomen

Senior Non Commissioned Officer (SNCO)	Warrant Officer (W/O)
	Flight Sergeant (F/S)
	Sergeant (SGT)
Junior Non Commissioned Officer (JNCO)	Corporal (CPL)
Junior Ranks	Leading Aircraftman (LAC)
	Aircraftman (AC)
Entry Level	Air Force Cadet

Training of Technical Personnel

To join the RNZAF as a Technical Tradesperson you must be a New Zealand citizen (some exceptions apply) of at least 17 years of age. Personnel enlist as Air Force Cadets and complete a 12 week recruit course covering basic military training. On graduation personnel are promoted to Aircraftman (AC). They then begin the Mechanics Course for their specialisation (e.g. avionics, composites) which for most technical specialisations takes between 24 and 31 weeks. Once the Mechanics Course is completed personnel undergo on the job training (OJT), carrying out duties and gaining experience on an RNZAF Base. Personnel are considered to have completed Primary Trade Training (PTT) on conclusion of OJT. The next phase is Advanced Trade Training (ATT) which involves a Technicians Course of approximately 13-40 weeks duration depending on the specialisation. On successful completion of ATT, personnel are considered to be fully qualified and are posted to a suitable unit. Their trade is permanently changed to

Technician (e.g. AVTECHs) at this time and they are usually promoted to Leading Aircraftman (LAC) shortly after finishing ATT.

Figure 11 displays the training and promotion process of an Avionics Technician. This is the process that most Technical Trade specialisations follow with the major difference being the length of the Mechanics and Technicians courses.

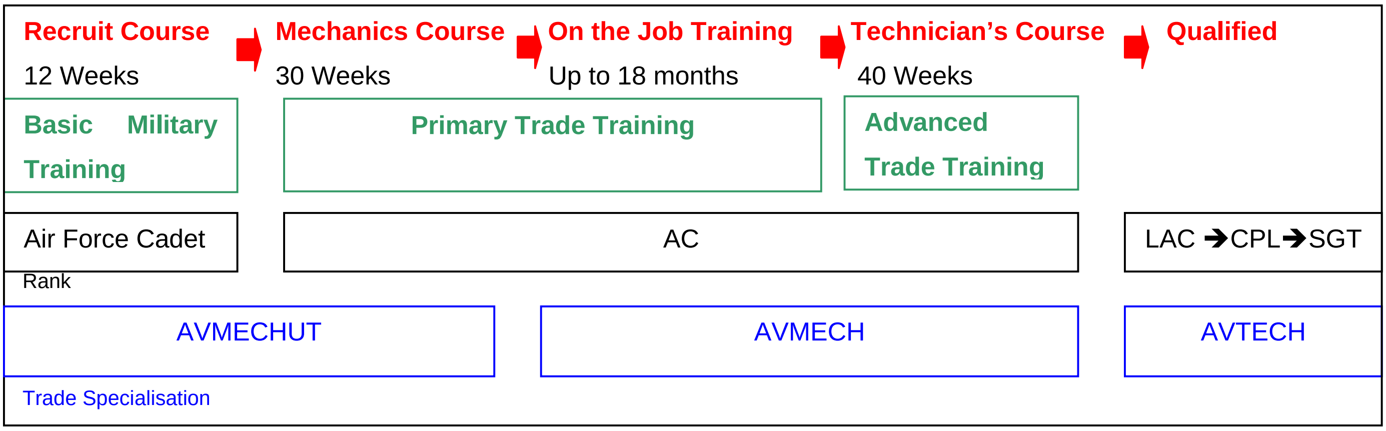

Figure 10: Training and Promotion Process for an Avionics Technician

Appendix B: Measures used in this Study

EMC

Please select the response that best describes the situation in your workplace in the RNZAF

1. For us, errors are very useful for improving the work process
2. After an error, people think through how to correct it
3. After an error has occurred, it is analysed thoroughly
4. If something went wrong, people take the time to think it through
5. After making a mistake, people try to analyse what caused it
6. People think a lot about how an error could have been avoided
7. An error provides important information for the continuation of the work
8. Our errors point us at what we can improve
9. When mastering a task, people can learn a lot from their mistakes
10. When an error has occurred, we usually know how to rectify it
11. When an error is made, it is corrected right away
12. Although we make mistakes, we don't let go of the final goal
13. When people are unable to correct an error by themselves, they turn to their colleagues
14. If people are unable to continue their work after an error, they can rely on others
15. When people make an error, they can ask others for advice on how to continue
16. When someone makes an error, (s)he shares it with others so that they don't make the same mistake

EAC

Please select the response that best describes the situation in your workplace in the RNZAF

17. In this workplace, people feel stressed when making mistakes
18. In general, people in this workplace feel embarrassed after making a mistake
19. People in this workplace are often afraid of making errors
20. In this workplace, people get upset and irritated if an error occurs
21. During their work, people are often concerned that errors might occur
22. Our motto is, "why admit an error when no one will find out"?
23. There is no point in discussing errors with others
24. There are advantages in covering up one's errors
25. People prefer to keep errors to themselves
26. Service members who admit their errors are asking for trouble
27. It can be harmful to make your errors known to others

28. Please provide examples of the types of errors you thought of when completing this section of the questionnaire___________________

Supervision

Please answer the following questions about your immediate supervisor
(E.g. SGT Supervisor if CPL/LAC/AC, F/S Supervisor if SGT)

29. My immediate supervisor is experienced in aviation maintenance
30. My supervisor really understands the maintenance task
31. I trust my supervisor
32. My supervisor sets clear goals and objectives for the team
33. My supervisor actively encourages team members to lift their level of performance
34. When I make an error, my supervisor will support me
35. My immediate supervisor checks my work very carefully

Stress

Please answer the following questions about yourself

How often do you feel stressed at work because of…..?

36. the task itself?
37. others at work?
38. secondary/additional duties?
39. work related issues/uncertainties?
40. problems outside of work?

Fatigue

Please answer the following questions about yourself

How often do you feel fatigued at work because of……?

41. the working hours?
42. the shift arrangements?
43. young family members sleep patterns?
44. other issues/activities outside of work?

GHQ

Please answer the following questions about yourself

Over the past few weeks to what extent have you…..

45. been able to concentrate on what you are doing?
46. lost much sleep over worry?
47. felt that you were playing a useful part in things?

48. felt capable of making decisions about things?
49. felt constantly under strain?
50. felt you couldn't overcome your difficulties?
51. been able to enjoy your normal day to day activities?
52. been able to face up to your problems?
53. been feeling unhappy or depressed?
54. been losing confidence in yourself?
55. been thinking of yourself as a worthless person?
56. been feeling reasonably happy, all things considered?

Violation Behaviour

57. I will temporarily disconnect or remove a part to make a job easier, but not document the disconnection/removal
58. Supervisors are prepared to sign for maintenance, trusting a tradesmen's competence, without performing the required supervision or inspection
59. Managers turn a blind eye to short cuts/risk taking by supervisors if the flying programme or task deadline is met
60. When given a task, I ensure that approved procedures are followed
61. Cheat sheets/personal notes are used in lieu of the publication or manual

Violation Attitude

62. Shortcuts are necessary in order to get a task done
63. It is necessary for me to take risks, other than those inherent in my job, in order to get a task done.
64. In my job there is a trade off between getting the task completed and doing it by the book
65. Where I work, tasks are performed in accordance with maintenance policy, process and procedure.

Errors

66. I have missed out steps in maintenance tasks
67. I have resumed at the wrong place when returning to a task after an interruption
68. I have lost a component part-way through a job
69. I have failed to detect a fault when completing a visual inspection
70. I have forgotten to check that all steps in a procedure were completed
71. I have forgotten to sign off a task
72. I have left a tool or some other item in an aircraft
73. I have installed a part the wrong way
74. I have found a part left over after a job was completed
75. I have had difficulty with a task because I misunderstood how a particular aircraft system worked

Demographics

76.	Position:	Mechanic / Technician / SNCO
77.	Trade:	Aircraft / Avionics / Small Trades
78.	Squadron:	3 / 5 / 6 / 40 / MSS / Avionics / DAC Advanced Technical Trade Training

If you would like to make any comments regarding this research, please do so here:

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Appendix C: Factor loadings for the rotated factors on the EAC Scale

Item	Factor Loading		Communality
	1	2	
1. In this workplace, people feel stressed when making mistakes		.807	.668
2. In general, people in this workplace feel embarrassed after making a mistake		.776	.616
3. People in this workplace are often afraid of making errors		.762	.632
4. In this workplace, people get upset and irritated if an error occurs		.685	.497
5. During their work, people are often concerned that errors might occur		.693	.491
6. Our motto is, "why admit an error when no one will find out"?	.754		.586
7. There is no point in discussing errors with others	.609		.374
8. There are advantages in covering up one's errors	.780		.609
9. People prefer to keep errors to themselves	.603		.407
10. Service members who admit their errors are asking for trouble	.715		.558
11. It can be harmful to make your errors known to others	.709		.578

Items with loadings less than 0.30 were omitted to improve clarity.

Appendix D: Factor loadings for the rotated factors on the Violations Scale

Item	Factor Loading 1	Factor Loading 2	Communality
1. I will temporarily disconnect or remove a part to make a job easier, but not document the disconnection/removal		.747	.559
2. Supervisors are prepared to sign for maintenance, trusting a tradesmen's competence, without performing the required supervision or inspection	.513		.324
3. Managers turn a blind eye to shortcuts/risk taking by supervisors if the flying program or task deadline is met	.816		.666
4. When given a task I ensure the approved procedures are followed		.792	.681
5. Cheat sheets/personal notes are used in lieu of the publication or manual		.539	.350
6. Shortcuts are necessary in order to get a task done	.620		.473
7. It is necessary for me to take risks other than those inherent in my job, in order to get a task done	.753		.570
8. In my job there is a trade off between getting a task completed and doing it by the book.	**.646**	.368	.553
9. Where I work, tasks are performed in accordance with maintenance policy, process and procedure		.662	.489

Items with loadings less than 0.30 were omitted to improve clarity.