Substandard Flight Crew Performance:

Recurrent Human Factors in Flight Crew Initiated Aircraft Incidents and Accidents

By

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ABSTRACT

The objective of this research has been to understand more about aviation accidents in which the actions of the flight crew members (hereafter FCMs) were the main cause. A new construct has been developed known as substandard flight crew performance (hereafter SFP) to provide framework and context for this research. To support this construct, the most recurrent examples of SFP were identified from analysis of decades of investigations and reports. Based upon the frequency of occurrence, the potential contribution to aviation safety, and the feasibility of conducting meaningful research, three diverse but interconnected factors have been identified. The first of these related to the recurrent influence of verbal phenomena in aviation accidents, in particular, distracting conversations and unclear communications. The literature indicated that even those tasked with investigating accidents where these phenomena had been present understood very little about the underlying reasons for their occurrence. Furthermore, although these phenomena have been studied within more general research populations, as far as is known no previous research has examined their function in the aviation context. A questionnaire and unstructured interviews with FCMs resulted in two taxonomies, both of which have been supported by ethnographic[1] observations. The next strand of this research critically examined some of the reasons why some flight crews become unsure of their position or orientation whilst navigating both in flight and on the ground, a phenomenon that has been associated with some of the most serious instances of SFP. This original contribution to aviation knowledge involved experiments utilising realistic navigation stimuli and measurement of cognitive load and spatial awareness. All human activity is embedded within a context, and this thesis contends that the influence of context is underspecified in existing knowledge of aviation human factors. As far as is known no previous research has

[1] Throughout this thesis, terms that are explained in the glossary are underlined.

examined how FCMs might be influenced to make errors as a result of aspects of their environmental and situational context. The contextual cueing strand of this research consisted of a series of original experiments which examined the extent to which contextual cues might be implicated in instances of SFP. The three research strands outlined in this thesis are intended to demonstrate how the detailed study of specific categories of SFP such as loss of positional awareness or unclear communications can unearth contributory factors that might otherwise have been overlooked. Furthermore, it will be demonstrated that each of the research strands addresses current issues at the forefront of aviation safety.

ACKNOWLEDGEMENTS

I would like to express my gratitude and appreciation to my supervisor, Professor Roy S. Kalawsky for his expert guidance support and encouragement during my research. He provided valuable objectivity as I sought to identify some of the abstract concepts outlined in the thesis. His grounding in the technical aspects of avionics meant that he understood much of what I was trying to achieve from the beginning of the research. He also gave me free rein to examine some of the soft science aspects of this research which were far removed from his background in the hard sciences. The access he provided to his other students was invaluable as I formulated my ideas for the research. I would also like to acknowledge the University's role in providing access to some of the most knowledgeable experts in a wide range of fields. I had occasion to access knowledge from experts in disciplines as diverse as linguistics and statistics; very few Universities could have provided this diversity in the way that Loughborough did. Thanks go to Martin Ashby in the research office who spent considerable time and effort helping me to design the conversation survey questionnaire. The University also provided advice regarding which computer programs would be most suitable for my studies. The provision of both the SPSS statistics program and the University's guidance on how best to use it was invaluable. The spatial awareness strand was based upon the SuperLab response time measurement software. There were several different incarnations of the experiments before the ones that feature in this thesis, some of them overly complex and difficult to design. The technical support experts at Cedrus in California were always polite and helpful as I attempted to explain what I was trying to achieve; their SuperLab is an excellent product and they know its capabilities very well. I am indebted to the management at Charleston Airport who permitted me to use their image of the Charleston accident and showed genuine interest in my perspective on the overrun accident at their airport. They have asked for sight of the completed thesis and I hope to do this. I would also like to acknowledge the assistance I received from dozens of pilots who contributed at all stages of this research. Pilots are sometimes wary of researchers so it was particularly generous of them to participate. Many showed a genuine interest and contributed insights that steered the research in the early stages. It is also important to acknowledge the work that goes into some of the occurrence reports that were the basis of much of this research. These reports are intended to further the interests of flight safety, and they certainly assisted in that objective in this research.

Research such as outlined here is time consuming and when combined with a full time job it leaves very little time for home and family. I would therefore like to acknowledge the support given by my family during the years that this study has taken.

DEDICATION

This thesis and the associated research are dedicated to all those aviation professionals who share in my passion for improved aviation safety through knowledge; I hope they find some of the content useful.

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GLOSSARY OF TERMS AND ABBREVIATIONS

ACARS	Aircraft communications addressing and reporting system is a digital data link system for the transmission of messages between aircraft and ground stations.
Allocentric orientation	An allocentric reference frame locates points within a framework external to the holder of the representation and independent of his or her position.
ASRS database	An American database for confidential aviation incident reporting.
ATC	Air traffic control: the controllers who control aircraft on the ground and in the air.
Autonomic nervous system	Part of the nervous system that serves the internal organs. After the autonomic nervous system receives information about the body and external environment, it responds by stimulating body processes, usually through the sympathetic division, or inhibiting them, usually through the parasympathetic division.
Avoidance-avoidance conflict	Conflict whereby one must choose between two more or less equally undesirable or unattractive goals.
Bald on record statement	A bald on record statement is a direct way of saying things without any minimisation to the imposition on the addressee.
Bank angle	The angle between the vertical and the angle the aircraft is inclined.
BEA	The French accident investigating authority.

Between-participants Design	In experimental design, a between-participants design is an experiment that has two or more groups of participants each being tested by a different testing factor simultaneously.
Bottom-up analysis	In bottom-up analysis sensory inputs are built and interpreted by the brain to result in a perception. In psychology, it refers to a process of progression from individual research elements to the whole.
Cardinal point	Each of the four main points of the compass (north, south, east, and west).
CFIT	Controlled flight into terrain.
Challenge and response	An interactive checklist procedure where one pilot challenges the other to make a response rather than just reading and doing the checklist.
Cognitive economy	The tendency for cognitive processes to minimize processing effort and resources.
Cognitive load	In cognitive psychology, cognitive load refers to the total amount of mental effort being used in the working memory.
Cognitive load theory	Cognitive load theory differentiates between three types of cognitive load, intrinsic, germane and extraneous.
Cognitive Map	A cognitive map is a mental image of the attributes of the environment.
Cognitive dissonance	Cognitive dissonance is a theory of human motivation that asserts that it is psychologically uncomfortable to hold contradictory cognitions.

Comment clause	A comment clause is a short word group (such as "you see" and "I think") that adds a parenthetical remark to another word group.
Concordancing	Involves a search for keywords and an examination of the context in which they appear.
Content validity	In psychometrics, content validity refers to the extent to which a measure represents all the facets of a given construct.
Conversation analysis	In sociolinguistics, conversation analysis is the study of the talk produced in ordinary human interactions.
Conversational turn	Turn taking is a conversational structure where participants speak one at a time in alternating turns.
Co-operative-Principle	A principle of conversation stating that conversational contributions should be suitable for their intended purpose.
Corrective Resolution Advisory (RA)	A TCAS alert issued to avoid a collision.
Critical discourse analysis	Critical discourse analysis is a contemporary approach to the study of language and discourses in social institutions.
CRM	Crew resource management; a set of protocols for efficient and safe aviation operations.
CVR	Cockpit voice recorder.
CVR Transcript	A transcript of a cockpit voice recording.
Decision speed	The speed on takeoff above which the pilot is committed to takeoff otherwise the aircraft will overrun the runway.

Delayed execution	A task that is deferred due to an environmental constraint.
Discourse analysis	Discourse analysis is a general term for a number of approaches to the analysis of written or vocal language.
Distance Measuring Equipment	An electronic instrument that depicts the distance to a radio beacon.
Downwind	The part of a landing pattern where the aeroplane travels parallel to the runway on a reciprocal track in order to correctly position for landing.
Ecological validity	Ecological validity refers to the extent to which the findings of a research study are able to be generalized to real life settings.
Electronic flight bag (EFB)	Electronic flight bag is a computer which stores and presents navigation charts, performance information and manuals allowing the flight deck to be paperless. (See Appendix F)
Egocentric orientation	An egocentric reference frame represents locations with respect to the perspective of the observer.
EGPWS	Enhanced ground proximity warning system. An electronic system that depicts high terrain on the ND and issues escape instructions if a collision with terrain is imminent. (See figure 8.4)
Enforced change of orientation	In this study, enforced change of orientation refers to any reorientation pilots need to achieve during navigation.

Ethnographic	Ethnographic research is widely accepted to refer to virtually any qualitative research project where the intent is to provide a detailed, in depth description of everyday life and practice.
Eurocontrol	The European organisation for the safety of air navigation, commonly known as Eurocontrol, is an international organisation working to achieve safe and seamless air traffic management across Europe.
Extraneous cognitive load	Extraneous cognitive load is caused by the way information or tasks are presented to a learner.
FAA	Federal Aviation Administration. The USA's aviation regulator.
Face threat avoidance	A face threatening act (FTA) is an act which challenges the face-wants of an interlocutor. Face threat avoidance strategies avoid FTAs.
Face-wants	The desire to satisfy the needs of negative and positive face.
Face-work	Face-work refers to the way that people cooperate to promote others' and their own sense of self-esteem, autonomy and solidarity in conversation.
First officer	A qualified pilot who is flying as second in command to a captain.
Flapless takeoff	Most airliners require some flap extension to takeoff safely; all the flapless takeoffs cited in this study were unintentional. Many airliners will be uncontrollable if flaps are not extended for takeoff.

Flight dispatcher	A licenced or unlicensed person who supports the flight crew during their preparations. In the USA flight dispatchers may share legal responsibility for some aspects of the safe operation of the flight.
Flight management computer (FMC)	A computer on the flight deck that processes route information and provides it to the displays. It also processes performance information. It is the nerve centre of the operation of the aircraft. See Appendix F for an illustration of an FMC.
fMRI	Functional magnetic resonance imaging is a neuroimaging procedure that measures brain activity by detecting changes in blood flow.
Go around	A procedure that pilots use to discontinue an approach to landing.
GPS	Global positioning system. A system that provides navigation information via satellites.
GPWS	Ground proximity warning system (See EGPWS).
Gulfstream	A type of business jet.
Hard science	Hard science refers to the natural sciences.
Holding pattern	A racetrack like pattern flown around a navigational fix with the intention of delaying the aircraft.
Homeostatic process	A process that maintains the body’s stability in the face of environmental changes.
HRO	High reliability organisations are those who have avoided catastrophes despite operating in a high risk environment.

Implicit learning	Implicit learning is the learning of complex information in an incidental manner, without awareness of what has been learned.
Intercept heading	A compass heading intended to converge upon the extended runway centreline.
Linguistic hedging	The use of a mitigating speech act to lessen the impact of an utterance.
LOC	Loss of control.
Magenta line	A magenta coloured line on the ND represents the active route. (See Figure 1.2)
Mental map	See cognitive map.
Mental rotation	Mental rotation is the ability to rotate mental representations of two dimensional and three dimensional objects as it is related to the visual representation of such rotation within the human mind.
Missed approach	A procedure that pilots use to discontinue an approach.
Mitigated directive	A mitigated directive softens an instruction.
Modal verb	An auxiliary verb that expresses necessity or possibility, such as *shall*, *will*, *should*, *would*, *can* or *could.*
Navigation display (ND)	An electronic moving map on the instrument panel.
Negative-face	Negative-face is the desire not to be imposed upon, intruded, or otherwise put upon.

North up	A map or display that depicts north at the top.
NPC	A non-pertinent conversation; one that is prohibited by the sterile cockpit rule.
NTSB	National Transport Safety Board: the agency that investigates accidents in the USA.
Observer centred	An observer centred reference frame represents locations with respect to the perspective of the observer. Also known as egocentric orientation.
One-tailed hypothesis	A one-tailed hypothesis predicts the nature of the effect of the independent variable on the dependent variable.
Operationalise/operationalising	In psychology, to operationalise is to measure a phenomenon and analyse those measurements.
Organisational citizenship behaviour	Organisational citizenship behaviour (OCB) is a term that encompasses anything positive and constructive that employees do of their own volition, which supports co-workers and benefits the organisation.
PF	The pilot flying the aircraft.
PM	The pilot monitoring the aircraft (i.e. not flying).
Positive-face	Positive-face is the desire to be liked, appreciated, approved of, etc.
Positive predictive value	The positive predictive value (PPV) is the degree of probability that a certain phenomenon will predict another one.
Post-completion error	A specific form of omission error occurring after some task or goal has been accomplished.

Power distance index	Hofstede's power distance index measures the extent to which the less powerful members of organisations and institutions accept and expect that power is distributed unequally.
Practice effect	Practice effects can be defined as influences on performance that arise from a practicing a task (Heiman, 2002).
Pragmatic competence	Pragmatic competence refers to the ability to use language appropriately in different social situations.
Predictive validity	Predictive validity is the extent to which the measure being used will allow you to make the predictions that should be possible with that measure.
Preventive resolution advisory (RA)	A TCAS alert issued to avoid a collision requiring no change to the aircraft's flight path.
Primary flight display (PFD)	An instrument that presents attitude, speed, heading and altitude information to the pilot.
Prosocial behaviour	Prosocial behavior refers to "voluntary actions that are intended to help or benefit another individual or group of individuals" (Eisenberg and Mussen 1989).
Prospective memory	Prospective memory is a form of memory that involves remembering to perform a planned action or intention at some future point in time.
Prototype	In this study, Rosch's (1973) definition of prototype is used. A prototype is a stimulus, which takes a salient position in the formation of a category as it is the first stimulus to be associated with that category.
Pull up	A speech act intended to convey that the pilot needs to climb immediately.

Radio altitude	Radio altitude is derived from a radio beam projected downwards. It is used close to the ground and is more accurate than barometric altitude.
Reciprocal	In the aviation context this means the 180 degree opposite direction.
Reference frame	A conventional way to describe the position and orientation is to attach a frame to it. For instance a north up chart adopts a northerly reference frame whereas a satnav in a car often adopts an observer centred reference frame.
Rejected takeoff	A manoeuvre involving discontinuing the takeoff and bringing the aircraft to a stop.
Response time	The length of time taken for a person or system to react to a given stimulus or event.
Resumption error	Error associated with resumption of a task after an interruption.
Schema	A mental structure of preconceived ideas, a framework representing some aspect of the world, or a system of organizing and perceiving new information.
Slips	Slips or action slips are unintentional behaviours resulting from a failure to pay due attention or absent mindedness.
SME	Subject matter expert.
Soft science	A colloquial term for the social sciences.

Speech act	In linguistics, a speech act is an utterance defined in terms of a speaker's intentions and the effects it has on a listener.
Stable approach	An approach to landing that meets established criteria in terms of alignment, speed and a range of other factors that ensure a safe landing.
Stall or stalling	In the aviation context a stall refers to a situation where the angle between the wing and the relative airflow is too high to sustain the lift required to support the aircraft.
Sterile cockpit rule	The sterile cockpit rule is a regulation requiring pilots to refrain from non-essential activities during critical phases of flight, normally below 10,000 feet.
Stick pusher	A device that physically pushes the control column forward in order to assist the recovery from a stall.
Stick shaker	A device that shakes the control column to alert the pilot that a stall is being approached.
TCAS	A traffic collision avoidance system designed to reduce the incidence of mid-air collisions.
TCAS manoeuvre	A manoeuvre in response to a TCAS alert.
Thematic analysis	Thematic analysis examines and records patterns within data and identifies themes which are arranged into categories for analysis.
Top-down Control	In the context of this research, top–down control of physiology concerns the direct regulation by the brain of physiological functions via the autonomic nervous system.

Trim or trimming	Trimming is a statistical process involving removing outlying data from a dataset.
UK AAIB	The UK's Air Accident Investigation Bureau.
UK CAA	UK aviation's regulatory agency.
Unstable Approach	An approach to landing that does not meet established criteria related to alignment, speed, height, rate of descent and thrust setting.
Wayfinding	In this research, wayfinding occurs when a pilot deviates from a pre-planned route.
Windshear	Windshear is defined as a sudden change of wind velocity.
Winsorize	Winsorizing involves identifying outlying data and replacing it with the closest valid value in the dataset.
Working memory	Working memory is short term memory which holds information in various different stores.

Substandard Flight Crew Performance:

Recurrent human factors in flight crew initiated aircraft incidents and accidents

PART I THESIS BACKGROUND

CHAPTER 1

INTRODUCTION

1. BACKGROUND

In recent years there has been a rapid increase in technology aimed at reducing the airline accident rate. For instance, according to IATA (2015) the steady reduction in controlled flight into terrain (CFIT) accidents over several decades can be traced back to the introduction of ground proximity warning systems. However, accidents in which the flight crew's actions are a causal or contributory factor are still overrepresented in the statistics; for this reason the current research focused upon recurrent human limitations and behaviours that have been evident in advance of safety occurrences in which technological safeguards have not been effective. The aviation occurrence literature acknowledges that there are likely to be variations in flight crew performance but when an unsafe level of performance is reached the term often used to describe such performance is "*substandard*"[i]. In line with the literature, the term substandard flight crew performance was chosen to encompass the phenomena described and researched in this thesis. To improve readability of the thesis, the accidents referred to by geographic location (e.g. the Lexington accident) are listed in alphabetic order in Appendix A with a brief description of the occurrence. Where a report or cockpit voice recorder (CVR) transcript is referred to in the text, the terms *report* or *transcript* are used. Two specific accidents provided the inspiration for this research, the first at Buffalo (NTSB, 2010a) near New York involved a loss of control which occurred in a context including a distracting conversation conducted by the flight crew when they should have been attending to the aircraft. The second was a runway overrun on takeoff at Lexington, Kentucky (NTSB, 2007a) which claimed 49 lives and also involved a flight crew who had been chatting whilst they should have been attending to the positioning of the aircraft. This was not the only trend evident in these two accidents; both flight crews had lost awareness of their spatial position, the former in terms of how close they were to the airport, and the latter in terms of the direction they were headed. Furthermore, each of these accidents occurred in contextual conditions that had been present in similar occurrences in the past. A serious concern is that since these two seminal accidents there have been further safety occurrences that have involved similar behavioural traits, human limitations and contextual conditions[ii]. The research outlined in this thesis examined three recurrent strands. The first was the influence of verbal phenomena upon flight safety. On the basis of commentary in the reports relating to the two accidents above, it was clear that although non-pertinent conversation on the flight deck was a known phenomenon there was very little understanding of the reasons it occurs with such frequency. As the research broadened from these two accidents it was also evident that many safety occurrences resulted from unclear communication or misinterpretation of a critical piece of information. The verbal strand of this research identified and explained a range of verbal phenomena that as far as is known, have not been considered in such depth in previous research. It was also evident from occurrence reports that the loss of spatial awareness evident at Buffalo and Lexington was a recurrent phenomenon in many of the documented safety occurrences. The occurrence literature also indicated that when flight crews became spatially disoriented, some of their core skills deteriorated to an unacceptable level very rapidly. The spatial awareness strand of the current research examined how cognitive load might be influenced by navigation tasks of the types evident the Jakarta accident, the Cali accident and others cited in this research. More specifically, this research examined how cognitive load is influenced by the requirement to mentally reorient from an observer-centred display to a map with a different reference-frame.

It was a natural progression for this research to examine why certain contexts appeared to promote substandard flight crew performance; this was the focus of the contextual cueing strand. At Lexington there were aspects of the airport lighting mentioned by the flight crew (NTSB, 2007a, p.65) before the accident that may have influenced their tolerance of the unusual lighting configuration they commented upon in the seconds before they crashed. If it could be demonstrated that this aspect of their context influenced their decision making processes then context becomes a major factor. Similarly at Buffalo the captain failed to perform the correct stall recovery. Instead of pushing forward on the control column he pulled back; although investigators were at a loss to understand why a trained pilot would do this, they underestimated the influence of context. This aircraft was on final approach when the stall warning occurred; in almost every conceivable situation that a pilot would need to discontinue an approach in the prevailing contextual conditions he would pull up rather than push the control column forward. By operationalising the role of context in aviation safety occurrences this research sought to explain how context might have been a factor in a wide range of safety occurrences.

THESIS OUTLINE

Part l consists of Chapters l to 4. Chapter 1 is a brief introduction to the background of the research outlined in this thesis. The aims and objectives are outlined along with the research scope. Chapter 2 outlines the types of aviation safety occurrences that have been occurring in recent years. The chapter contends that a problem exists in relation to aviation safety that is not being fully addressed at present. This theme is developed by highlighting some of the limitations of both the way that human error is conceptualised in the aviation context and how the data derived from reports and investigations is presented for analysis. Chapter 2 concludes that a construct that placed more emphasis upon human limitations and behaviour would complement existing models of human error causation. Chapter 3 introduces the substandard flight crew performance (SFP) construct and identifies what is and is not SFP for the purposes of this research. An explanation of the rationale behind the choice of the three research strands is followed by an example of an SFP-related accident from the literature. Chapter 4 outlines the ethnographic orientation of the research by introducing institutional features of the airline context that will feature in greater detail later in the thesis. This is followed by a description of the conceptual model used in the development of this research highlighting some of the differences between a system-world and a real-world perspective on aviation safety. The reasons for adopting this conceptual model are explained by a detailed examination of aviation's stakeholders and their motivations. This section outlines the worldview of the aviation system that is scrutinised in this study. The chapter concludes with a description of some of the transformations that could flow from a better understanding of substandard flight crew performance. Part II starts with Chapter 5 which describes in detail the basis for a mixed methods approach employed in this research and introduces the literature and research upon which this study was founded. Chapter 6 outlines the research methods used for each strand and then outlines in detail how the research was conducted. Part III describes in detail the research that underlies the methods outlined in Chapter 6. The rationale behind the experiments is described and then the results and analysis are presented. Part IV discusses the conclusions that can be drawn from the research, its contribution to the field and its implications for the future of flight safety. Figure 1.1 illustrates the thesis layout.

Figure 1.1: THESIS LAYOUT

PART I: THESIS BACKGROUND	•CHAPTER 1 INTRODUCTION, AIMS, OBJECTIVES AND RESEARCH SCOPE •CHAPTER 2 EVIDENCE OF A PROBLEM REQUIRING A SOLUTION •CHAPTER 3 SUBSTANDARD FLIGHT CREW PERFORMANCE (SFP) •CHAPTER 4 THE METHOD OF ENQUIRY EMPLOYED IN THIS RESEARCH
PART II: EXPERIMENTAL APPROACH AND RESEARCH METHODS	•CHAPTER 5 BASIS FOR AN EXPERIMENTAL APPROACH TO THE STUDY OF SFP •CHAPTER 6 RESEARCH METHODS
PART III: RESEARCH RATIONALE, RESULTS, ANALYSIS AND DISCUSSION	•CHAPTER 7 THE VERBAL STRAND RESEARCH AND EXPERIMENTS •CHAPTER 8 THE SPATIAL AWARENESS STRAND RESEARCH AND EXPERIMENTS •CHAPTER 9 THE CONTEXTUAL CUEING STRAND AND EXPERIMENTS
PART IV: IMPLICATIONS OF THE ENTIRE RESEARCH	•CHAPTER 10 FINAL CONCLUSIONS, RESEARCH CONTRIBUTIONS AND IMPLICATIONS FOR AVIATION SAFETY

1.1 RESEARCH AIMS

The primary aim of this research was to propose a new construct called substandard flight crew performance (SFP) and to demonstrate how it could be used as a repository for knowledge relating to specific categories of safety occurrences which have been underspecified in the past. A further aim of this thesis was to demonstrate how by categorising safety occurrences on the basis of recurrent instances of a particular human limitation or type of behaviour it would be possible to identify causal links that might otherwise be overlooked. The verbal strand of this research examined non-pertinent conversation and unclear communications. The first aim of the non-pertinent conversation study was to determine whether the phenomenon of the non-pertinent conversation was researchable because despite its presence in the aviation occurrence literature for over forty years, the aviation regulators and investigators remain unable to understand why these distracting conversations are such a recurrent feature of a very diverse range of aviation accidents. Another important aim was to identify the underlying reasons that these distracting conversations take place, with a view to mitigating their effect.

Decades of accident reports also indicate that failure to communicate effectively is a persistent feature of SFP related airline accidents involving fully serviceable aircraft but despite investigators and regulators being able to recognise unclear communication when they encounter it, investigations into serious incidents such as occurred at St Kitts (UK AAIB, 2010a) indicate that even they struggle to understand why it occurs. Unclear communication on the flight deck follows repetitive patterns, with a reluctance to speak up, particularly among subordinate FCMs, being among one of the most recurrent characteristics. The aim of this research was to identify some of the recurrent instances of unclear communication in the aviation occurrence literature and propose some reasons for their occurrence so that its effects might be mitigated.

In accidents spanning several decades it was clear that the flight crew had lost either spatial or situational awareness despite the availability of a moving map navigation display (ND) similar to the one in Figure 1.2 below.

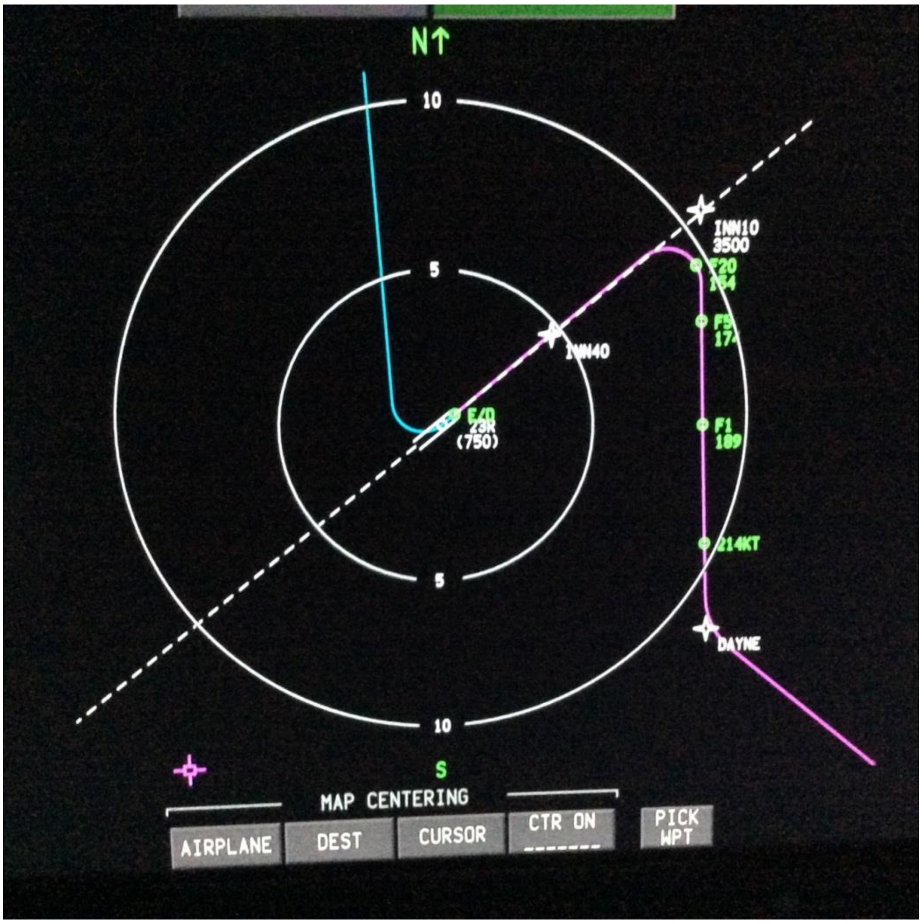


Figure 1.2: A navigation display. The magenta coloured line is the programmed route and the green numbers show the speed and position at which the flaps should be extended.

The aim of the spatial awareness strand research was to examine how flight crews' cognitive load is affected when they face a spatial-awareness task involving reorientation from an observer-centred display to a map with a different reference-frame.

Throughout this research it emerged that particular categories of accident often occurred within a contextual environment that had prevailed in a previous similar accident. The observation that on occasions contextual information appeared to have adversely influenced FCMs' actions led to an examination of the influence of contextual cueing in SFP. This is a concept that has received almost no previous attention in the aviation literature despite being

described in the reports into seminal accidents at Tenerife in 1977 (Ministerio de Transportes y Communicaciones Subsecretaria de Aviacion Civil, 1978), in Cali, Colombia in 1995 (Flight Safety Foundation, 1998) and more recently in Miami in 2015 (QCAA, 2015).
In addition to elaborating on the concept of contextual cueing, which has largely been associated with visual stimuli, an important aim of this research was to operationalise contextual cueing in the aviation context and propose and test three aviation-specific hypotheses.

In combination, the three strands of this research (verbal communication, spatial awareness and contextual cueing) addressed human limitations that were implicated to a varying extent in many of the most serious aviation accidents documented in recent history.

1.2 RESEARCH OBJECTIVES

THE VERBAL STRAND CONVERSATION RESEARCH

The objective of the conversation research was to develop taxonomies of the most recurrent flight deck conversation topics and their underpinnings validated by surveying current pilots, and to propose explanations for their occurrence based upon peer-reviewed research. This objective addressed a deficit in existing knowledge of the phenomenon of the non-pertinent conversation highlighted in both the Lexington (NTSB, 2007a) and Buffalo (NTSB, 2010a) reports. This research asked questions relating to the types of conversations that take place and why they occur.

THE UNCLEAR COMMUNICATION RESEARCH

Recent safety occurrences at St Kitts (UK AAIB, 2010a) and Birmingham, Alabama (NTSB, 2014b) indicate that some aviation practitioners do not understand what constitutes clear and unequivocal communication. The objective of this research was to conduct a textual analysis of several accident CVR transcripts to identify recurrent instances of unclear communication. With reference to the linguistic literature, explanations for some of the most recurrent instances of unclear flight deck communications are proposed. As far as is known, this is the first research to develop a taxonomy of aviation-related unclear communication based upon the linguistics literature. It is also believed that some of the explanations are original to this research.

THE SPATIAL AWARENESS STRAND RESEARCH

The objective of the spatial awareness strand research was to conduct experiments to examine the rapid decrease in flight crew performance that sometimes accompanies a sudden unexpected spatial awareness task. If it can be demonstrated experimentally that cognitive load varies with the type of spatial awareness task required then such tasks could be implicated in documented instances of substandard flight crew performance. The necessity for a better understanding of the link between spatial-awareness tasks and deficits in flight crew performance was evident in the reports into accidents at Islamabad (PCAA, 2010) and Jakarta (KNKT, 2012), neither of which mentioned the influence of the spatial awareness challenges faced by the pilot involved. The two spatial awareness experiments posed questions relating to real life orientation tasks and their effect upon cognitive load.

THE CONTEXTUAL CUEING STRAND

The objective of the contextual cueing strand experiments and research was to establish a new and original construct that has been described in the aviation literature but as far as is known has not previously been operationalised. Experiments were used to examine two of the three hypotheses proposed. A third hypothesis was examined with reference to the occurrence literature. Aspects of contextual cueing are evident in many of the safety occurrences outlined in this thesis.

In combination the aims and objectives outlined above are intended to illustrate how SFP-related research is conducted and how the SFP construct can provide a repository for such knowledge.

WHY IS THE SFP CONSTRUCT NEEDED?

A premise of the research outlined in this thesis is that by categorising safety occurrences on the basis of human behavioural traits and limitations rather than by their technical characteristics it will be possible to collate knowledge from a wide range of occurrences, some of which might appear to be unconnected. To illustrate the point being made, there is a current and emergent threat related to flight crews who lose control of their aircraft whilst climbing out after a takeoff or missed approach; these instances are almost always categorised as loss of control (LOC) occurrences, and although human error is rarely explicitly cited as the cause, it is clear that the actions of the pilots are implicated. However, a detailed reading of the occurrence literature indicated that in several cases the LOC had occurred shortly after a confusing or ill-timed communication from air traffic control. This phenomenon is not unique to the takeoff/missed approach situation, having been a factor in runway safety, and CFIT occurrences as well. The SFP construct contends that a factor such as unclear communication, whether it occurs during a missed approach, at the parking gate, whilst taxing or at any other time, possesses recurrent characteristics which on the basis of the literature are unknown to some pilots and support workers. It is not being suggested that there is no value in categorising the occurrences above as LOC instances, this already happens. What is being proposed is that by having a category such as *unclear communication* containing all that is known about the subject, explanations emerge that would have otherwise been missed. An example is found in the Buffalo and Lexington accidents, which had no similarities whatsoever in technical terms but were closely linked in terms of the verbal behaviours exhibited by the pilots. Support for the approach outlined in this thesis is found in the fact that the report into the Buffalo accident (NTSB, 2010a, p. 100) referred its readers to the Lexington (NTSB, 2007a) accident report as a reference for the similarities between the verbal behaviour of the two flight crews; had the SFP construct been available to the investigation there would have been far more information and theory-based explanations available.

The three diverse strands of this research are not based simply upon intuition; each was chosen in direct response to unanswered questions in the aviation safety literature. For instance, the two very dissimilar accidents cited above occurred in a context which featured unauthorised and distracting conversations. The reasons why pilots who were aware that their conversations carried the risk of distraction and that they were unauthorised, behaved in the way they did remained unresolved at the conclusion of the respective formal investigations. Non-pertinent conversations (NPCs) have persistently defied explanation even by senior investigators such as Deborah Hersman, who is a former chairman of the NTSB (See NTSB, 2010a. p. 110).

Two recent accidents, one at Islamabad (PCAA, 2010) and one at Jakarta (KNKT, 2012) prompted the spatial awareness strand of this research. Although both of these accidents were attributed to the actions of the pilots, there are similarities that suggest that a secondary task such as manipulating autopilot controls (as was the case in both of these accidents) can become degraded during a period when a cognitive map of the spatial environment needs to be constructed. If this is the case, neither of the two reports just cited provided any insight into the cognitive processes that might have been involved. Research into wayfinding provided several of the ideas outlined in the spatial awareness strand of this research. Several themes emerged from a detailed study of related accidents. Pilots appear to fly and navigate uncharacteristically badly when they are involved in sudden unexpected changes to their planned route, and the deterioration can be very rapid indeed. It was also clear that in many such accidents the flight crew, for a number of reasons, did not make use of the egocentrically-oriented navigation display. The pilots at Jakarta were flying the most modern airliner available at the time, but they still resorted to mental arithmetic to derive their heading to their destination in the minute before they flew into terrain. Although the focus of this study was on modern aircraft with electronic navigation displays, an instance at Tenerife in 1979 involving a Boeing 727 (UK AIB, 1981) with analogue instrumentation bore several similarities with contemporary accidents. The accident literature indicates that pilots of modern aircraft equipped with egocentrically-oriented navigation displays (NDs) may gain little advantage from such technology when navigating off their programmed route. In fact studies involving other research populations suggest flight crews of ND equipped aircraft may even be less well prepared for navigating off their planned route than those who are accustomed to maintaining a mental map of their spatial environment. Whilst it is understandable that flight crews may be temporarily unsure of their position during such unplanned changes, less is understood about why they sometimes lose control of the aircraft or fail to perform even well-rehearsed actions such as turning the heading selector or responding to an alert. An important aim of this research was examine how certain spatial tasks might influence flight crews' cognitive load and to relate this to their performance of concurrent tasks. This research examined two types of spatial task that the literature indicates have been part of the context that has preceded an accident. The first involved measurement of cognitive load when transitioning from an egocentric orientation to a northerly oriented map; this task was being undertaken shortly before an accident at Cali in Columbia (See Flight Safety Foundation, 1998, p. 23). The second task examines perspective-taking; flight crews need to be able to imagine scenes that they are not currently experiencing, such as when they make decisions relating to parallel runways before they are aligned with them. An accident in the Comoros Islands (Union des Comores, 2013) involved a flight crew stalling a completely serviceable Airbus into the sea whilst performing a circling approach which would probably have involved this type of spatial task. The official report commented on the mental resources needed to fly such an approach. This was a demanding approach in which the pilot flying in the left hand seat would need to have visualised a runway on his right and its surrounding terrain whilst flying on a reciprocal heading; this is the type of scenario that this study contends results in increased cognitive load. The report did not elaborate on the reasons why the Comoros flight crew may have exceeded their mental capacity when this was actually one of the most important questions that required an answer. This is the type of question the SFP construct is intended to address.

Because aviation boasts a highly developed store of human factors knowledge, proposing a new aviation related human factor construct is not embarked upon lightly, but based upon the researcher's experience of four decades of airline flying, coupled with an academic grounding in psychology, it was considered that the increased focus upon recurrent human limitations and behaviour of the SFP construct outlined in this thesis would represent a significant contribution to aviation safety. The current research set out to demonstrate how disparate occurrences, sometimes separated by decades, often share similar human factors related characteristics that can be researched and explained. Notably, the Buffalo accident report (NTSB, 2010a, pp. 100-101) pre-empted the SFP construct when an emerging narrative surrounding pilot professionalism informally drew parallels between the behaviour seen in the Lexington runway crash and the Buffalo loss of control, and it was this narrative that inspired the verbal strand of this research. The current study elaborated upon the notion that an accident represents the outcome of a chain of events that usually starts with a set of contextual conditions such as the flight crew chatting when they shouldn't be, or a controller passing an incomprehensible or ill-timed instruction, or simply because the situational context has a trap of which the FCMs are unaware. The SFP construct shifts the focus from categorising safety occurrences on the basis of their outcome to a categorisation based upon the behavioural, situational and contextual factors that facilitated the occurrence.

An SFP-related examination of the Lexington and Buffalo accidents would access SFP's *non-pertinent conversation* category of instances, whilst more traditional examination of the technical characteristics of the occurrence could occur in parallel. SFP- related explanations would reduce the need for reports to cross refer to previous accident reports for explanations, which is frequently the approach adopted at present. The SFP construct is intended to provide a repository for knowledge relating to specific occurrence precursors such as *unclear communication* or *loss of spatial awareness* so that members of the aviation safety system at all levels can identify them and mitigate their effects. This thesis describes a worked example of how the SFP construct could be used as a means of identifying and explaining human behaviour related to some of the most recurrent phenomena in aviation safety occurrences.

1.3 RESEARCH SCOPE

The scope of investigation related to any aviation accident or incident involving any of the following factors:

- Evidence of a non-pertinent conversation (NPC).

It was extremely important to identify CVR transcripts in which an NPC had not only been present but was likely to have been a contributory factor. There were several instances were a report highlighted that an NPC had taken place but upon careful reading it had not been a factor in the occurrence. There are also instances such as the Hudson River Airbus ditching where an NPC was evident in the transcript (NTSB, 2010b, p.146) but was not even mentioned in the report. This research only considered four transcripts to be suitably complete and relevant to form the foundation of the NPC research. Transcripts which had been edited were treated with caution although some contained useful data. There was no limit upon the age of the transcript as long as it was relevant. The conversation section of the verbal strand research was not concerned with linguistic features of conversation but the interactional functions of conversation.

- Evidence of unclear communications.

Deciding what is clear or unclear is likely to be subjective but often the outcome of an occurrence indicated how effectively a message had been communicated. This study was not concerned with language comprehension problems although some useful insights were gained from transcripts which involved translations from a foreign language, suggesting the phenomena under examination may be generalizable across cultures. Neither was it concerned with the rate of speech or the influence of accent; all of these phenomena have been studied elsewhere (e.g. CAA, 2017). This research differed from conversation analysis (CA) of the type conducted by Nevile & Walker (2005) inasmuch as they had access to actual recordings so they were able to draw inferences based upon pauses and intonations that were not possible from transcripts alone. Whilst CA research might be able to determine what a speech act such as *okay* was intended to mean, this research could only present the alternative meanings for the reader to make a judgement. The data for this study were distinct from Nevile and Walker's data consisting of phenomena such as nuances, hedges and mitigated directives, the functions of which were already well-documented in more general linguistic research and were able to be adapted to the aviation context.

- Evidence that the flight crew performance deteriorated after they lost track of their position, orientation or aircraft state.

This was not a situational awareness study; this has been more than adequately described in a body of work by Mica Endsley (See Wickens, 2008 for a review). This research was also not primarily concerned with pilots who lose positional awareness but continue to fly the aircraft competently. The focus of attention was upon those few pilots who become so confused during a period of spatial awareness challenge that they become unable to perform tasks that they would normally be able to. So whilst the previously cited accident flight crew at Cali would qualify for inclusion because they lost control of their aircraft, the flight crew involved in a CFIT accident at Arkansas (NTSB, 1974) who lost positional awareness to the extent they hardly knew which state they were in would not, because they were under control when they hit the terrain. Notably, the Cali accident report outlined by the Flight Safety Foundation (1998) did not consider the influence of spatial reorientation upon the flight crew's performance and this is the case with many similar reports, so careful analysis and interpretation of the reports was necessary. For instance in two LOC instances reviewed for this research, although the pilot faced spatial awareness challenges there were concurrent distractions that may have been a more influential factor so these accidents were excluded from analysis on the basis of spatial awareness.

- Evidence that the flight crew appeared to have been had adversely influenced by their contextual situation.

This includes any instance where a flight crew performs or omits an action that they would not have performed or omitted if not for the prevailing contextual cues. Because this is believed to be a new construct in the aviation context it is difficult to exclude any specific types of occurrence. It is however, possible to outline some of the occurrences that appear to be unduly affected by contextual cues. Wrong runway takeoffs, landing gear retracted approaches, and flapless takeoffs are all example of serious errors that, according to the reports, could have been influenced by contextual factors. Despite being a new construct, contextual cueing emerged as a prolific feature of SFP related occurrences; for instance the most recent serious incident report issued by the UK AAIB (2016) describes a LOC occurrence where a captain had built up a false expectation that a lightning strike would result in the autopilot disconnecting, based partly upon a simulated scenario he had experienced during recurrent training. In the absence of witnessing that scenario it is debatable whether the error that nearly resulted in the loss of the aircraft would have occurred.

CHAPTER 2

EVIDENCE OF A PROBLEM REQUIRING A SOLUTION

OVERVIEW

HUMAN ERROR AND AVIATION SAFETY: THE CURRENT STATE OF AFFAIRS

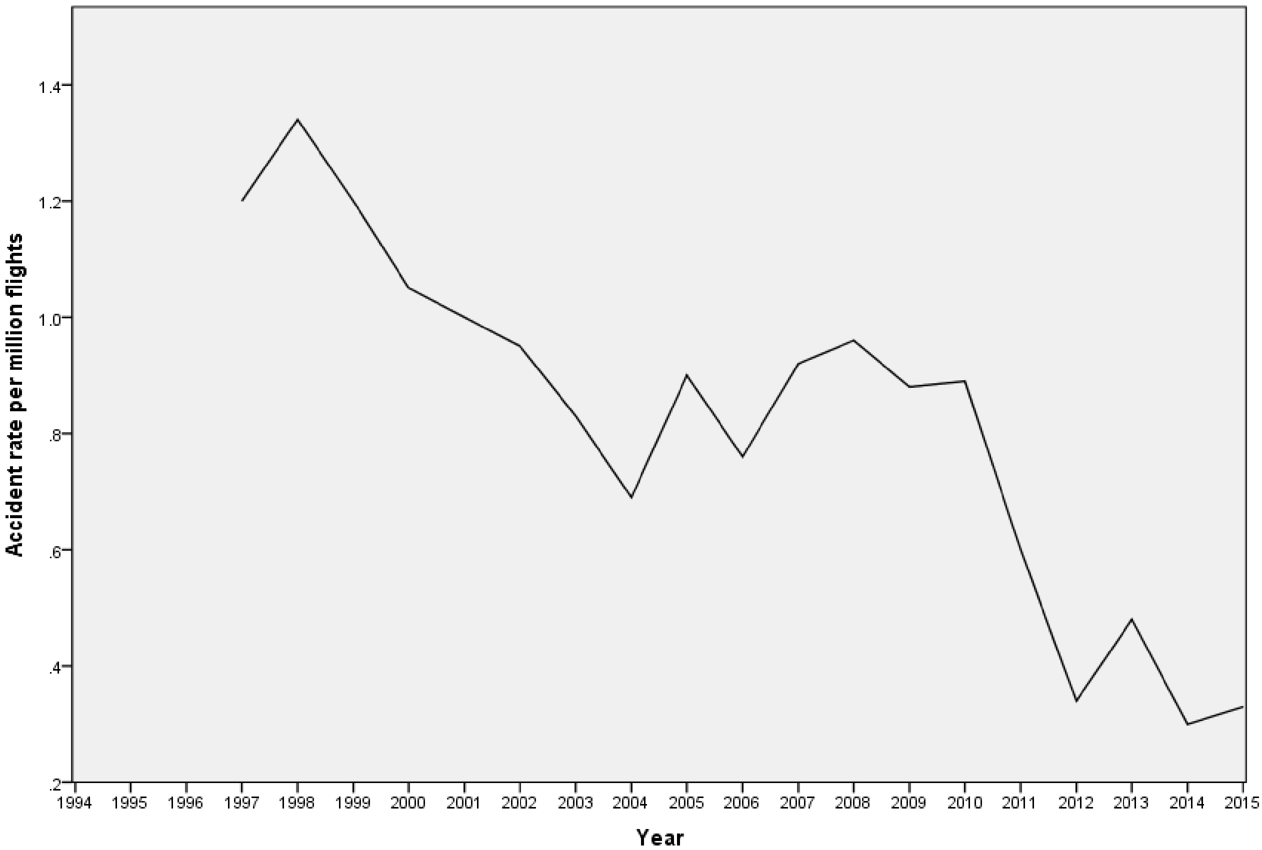
UK CAA statistics indicate that commercial flying is one of the safest modes of transport, and the UK has an excellent aviation safety record. In terms of large commercially operated aeroplanes the UK's fatal accident rate is amongst the lowest in Europe, which at 17% is amongst the lowest worldwide (CAA, 2014, p. 16). However, as technological advances and mechanical reliability have improved, an unfortunate consequence is that an increasing proportion of those accidents that still occur result not from mechanical failures but from human error. Aviation comprises multiple complex systems and there is evidence that, at times the level of human performance that these systems demand is simply higher than can be reasonably expected. Even the most professional and competent human beings will occasionally vary performance or do something they did not intend. If people cannot perform their safety critical tasks to the level required, then circumstances must change to allow them to perform better or the system must change to reduce the reliance on their correct performance and so ensure safety is maintained. During the decade between 2002 and 2011, 7148 people were killed in 250 fatal airline accidents worldwide (CAA, 2014, p. 84) but only 38% of these involved a factor affecting the airworthiness of the aircraft, meaning that the remainder involved fully serviceable aircraft. Substandard aircraft handling by the pilot was one of the most frequently allocated causal or contributory factors, as was the performance of an inappropriate action. Omissions such as failing to observe safe altitudes or forgetting to configure the aircraft for takeoff were also recurrent causes. The current study was motivated by the fact that according to the CAA (2014, p. 84) over 60% worldwide fatal accidents involved serviceable aircraft with qualified crews.

2.1 THE TYPES OF FLIGHT CREW INITIATED AIRLINE ACCIDENTS WHICH OCCURRED IN THE DECADE BETWEEN 2002 AND 2011

According to the latest CAA statistics (2014) among the most frequently occurring fatal accidents between 2002 and 2011 involving serviceable aircraft were from the categories controlled flight into terrain (CFIT) and loss of control (LOC). Although there was only one fatal runway accident in the period (the Lexington accident) this thesis will cite several runway related occurrences that could have easily resulted in *runway safety* (RS) occupying a far higher ranking in the statistics. Runway safety (RS) encompasses accidents and incidents where a flight crew enter the runway at an incorrect position or line up on the wrong runway or in some cases on a taxiway. Incorrect configuration take offs (such as using an incorrect power, flap or trim setting) have also qualified as RS events in the past. Fully developed RS accidents such as the one at Lexington (NTSB, 2007a) are very costly in terms of loss of life but the majority of serious RS events do not result in an accident and therefore are not reflected in the accident statistics. There is however, a comprehensive literature (See Flight Safety Foundation, 2009: ICAO, 2007) relating to RS incidents suggesting that RS is among the most serious risks to aviation safety at present.

Loss of control (LOC) occurs when a pilot flies outside the normal flight envelope resulting in the aircraft becoming uncontrollable. Although documented instances of LOC such as the Trident accident at Staines, UK (UK AIB, 1973) date back to the 1970s and earlier, recent history indicates that LOC remains a persistent threat to aviation safety. There is a current initiative to focus upon airline pilots' ability to recover from LOC occurrences but modern high performance airliners can become uncontrollable in seconds if timely recovery is not initiated. According to the CAA research cited above, nearly 40% of all fatal accidents involved some kind of loss of control, making this the most frequent type of accident during the decade to 2011. Non-technical failures (for example flight crew failing to correctly respond to a warning) were the predominant cause of LOC accidents. Mirroring the comments above about RS, it is important to emphasise that for every LOC fatal accident there are multiple lucky escapes that appear in the incident literature but are not reflected in fatal accident statistics. By way of illustration, since 2007 there have been three reportable LOC incidents [iii]in the UK alone that were serious enough to be investigated by the UK AAIB and many more worldwide. In terms of hull losses, the worldwide accident rate has been steadily decreasing in recent years (See Figure 2.1). However, these statistics are not sensitive enough for the purposes of this research. For instance although according to IATA statistics (2015) collision with terrain (CFIT) accidents have steadily declined since the advent of terrain warning systems in the late 1970s, several recent CFIT accidents, one in Islamabad (PCAA, 2010) one in Jakarta (KNKT, 2012) and one in Birmingham, Alabama (NTSB, 2014) indicate how the data can become skewed by very few occurrences.

Figure 2.1: Yearly accident rate per million flights
(Source: Boeing Commercial Airplanes 2016)



2.2 THE LIMITATIONS OF STATISTICAL DATA RELATING TO AVIATION SAFETY

Although the CAA data summarised above represent an example of reporting and analysis at its highest level, its limitations demonstrate the difficulty that researchers encounter when basing this type of research upon statistics from around the world. The CAA report notes that accident reporting criteria are not consistent throughout the world, so the number of factors assigned to fatal accidents may vary widely amongst the different operator regions. The CAA analysis is complex, with the possibility of assigning any number of 132 causal factors to each accident. Despite the completeness of the CAA data, unfortunately anomalies are evident. For instance, the runway accident at Lexington (NTSB, 2007a) is categorised as a runway incursion; although this is technically correct, this categorisation disguises the fact that this was far more than a runway incursion. More precisely, the Lexington accident was an instance of a *wrong runway takeoff*, a category which rarely results in fatalities or indeed any negative outcomes whatsoever. However, each flight crew that takes off or lands on the wrong runway or a taxiway has avoided a catastrophe purely due to luck. Although the Lexington accident was a rare event, very similar events are documented but they are not necessarily reflected in the accident statistics. In defence of the CAA statistics it is important to emphasise that prior to the Lexington accident the incidence of fatal accidents involving a wrong runway takeoff was very low but it does illustrate how even high quality statistical research can fail to reveal emerging trends. An example of a very serious incident that could easily have been an accident, involved a Scandinavian Boeing 737 flight crew who took off in fog at Lulea, Sweden on the reciprocal runway to the one they had been cleared to take off from. Despite the similarity to the Lexington accident, the report into this serious incident (Statens Haverikomission, 2009) considered this occurrence to be a *wrong runway takeoff* rather than a *runway incursion;* furthermore, as there was no negative outcome, this occurrence does not feature in the accidents statistics despite its seriousness. This example highlights one of the problems of searching the literature based upon even the most respected sources. A further problem arises when attempting to cross reference similar instances that have been categorised in different ways. Although the accident at Lexington (NTSB, 2007a) involved very similar human limitations to those evident at Lulea there was no reference whatsoever in the Lulea report to the accident at Lexington despite the fact that it was the most serious similar instance in recent history and was high in the consciousness of the aviation community in general at the time. This absence of cross referencing may be no more than lack of vision on the part of the investigators or it may represent a reluctance to acknowledge that the only reason a catastrophe was averted was good luck. There was considerable evidence in the reports examined for this research of under reporting and of failing to acknowledge similarities between fatal accidents and incidents, which by good fortune had not resulted in an accident. There was also a noticeable tendency in some reports to provide incomplete data in relation to flight crew related factors[iv]. This phenomenon was also noticed by the CAA (2014), who commented that this may be due to the factors either not being apparent to the investigators or not being thought to be worthy of inclusion in a summary report. If the former reason is correct, it implies a gap in knowledge at a high level; if the latter is correct then this research provides evidence to the contrary. Another important explanation for the tendency to shy away from human factor based explanations may be associated with the mission statements of many investigating agencies, which explicitly avoid the apportioning of blame. For this reason they might find it problematic to delve too deeply into human factors, which by definition attach some blame to the individual. Notably, the NTSB in the USA and the BEA in France are not constrained in this way and if a human factor attaches to an individual they go ahead and highlight it. Although this is a refreshingly candid approach to investigation it makes comparison of instances very challenging. The current research would have been facilitated by a database that included for instance, all loss of control safety occurrences during an unexpected go around **(**of which there are many, the most recent at Rostov, Russia: See Interstate Aviation Committee, 2016) but the literature review conducted for this research indicated that this would be impracticable because of the multiple sources that would need to be accessed. Some of the most useful leads to relevant incidents came from internet chat forums which alluded to an incident in some far corner of the globe that led to a report that would never have been located otherwise. Notably, several plausible reports on such forums resulted in no official report being located, which cast further doubt on the reliability of incident statistics. The suggestion that some serious incidents go unreported is not just based upon anecdotal evidence, there were several reports citing instances of a serious incident that had only been discovered after considerable investigation following a serious accident[v]. Furthermore, some trusted major airlines are permitted to conduct their own investigations into incidents, which sometimes do not reach the public domain for a variety of reasons. It would be naïve to dismiss the possibility that various stakeholders might have an interest in not publicising incidents that might reflect negatively on them. None of these limitations invalidate the use of accident and incident statistics but they do call for the exercise of caution when reaching conclusions. The NASA ASRS database contains a useful caveat regarding the use of their influential data (See Appendix C) which highlights that quantitative analysis might not be the most effective way of analysing their data but if it is necessary, the number of reports of a particular type of event should be considered a "lower measure" of the number of such events occurring. The message from the CAA analysis was loud and clear; approximately 60% of fatal airline accidents that occurred between 2002 and 2011 were caused by pilots who flew to a substandard level of performance. Whilst having access to 132 causal factors, as was the case in the CAA analysis, is likely to increase the statistical power of any conclusions drawn, it tends to conceal the fact that each of these instances was due to the pilots' substandard performance. This phenomenon has traditionally been known as human error or pilot error; in section 2.3 some of the limitations of this traditional view are outlined and in section 3.1, a new way of conceptualising the substandard flight crew performance described in this study, is proposed.

2.3 THE LIMITATIONS OF THE HUMAN ERROR CAUSATION WHEN APPLIED TO AVIATION

Although the term *pilot error* is not widely used within the aviation industry its use is commonplace in wider society. An illustrative example is found in some of the press reports of a taxiing accident involving a British Airways 747 at Johannesburg (Kithching, 2015) which were quick to attribute the accident to pilot error despite the fact that the official report

(SACAA, 2014) had not used the term. However, investigations and the reports they produce are intended for a variety of audiences so it is understandable if on occasions there is a tendency to report findings in such a way that the readership is likely to understand. In fact, in the accident just cited the flight crew did make some errors but they were far from the root cause of the accident. Human error has been conceptualised in various ways; writing in the British Medical Journal, James Reason (2000) provided a useful distinction between the *person* approach and the *system* approach. In the former, unsafe acts, errors and procedural violations enacted by people at the sharp end, such as nurses, physicians, surgeons and pilots arise primarily from aberrant mental processes such as forgetfulness, inattention, poor motivation, carelessness, negligence, and recklessness. Careful reading of the Johannesburg accident report cited above provided little evidence of these phenomena. Reason's conclusion that the person approach usually results in countermeasures directed at reducing unwanted variability in human behaviour illustrates the inadequacy of thinking about many aviation accidents in this way because as is often the case, this flight crew's behaviour was not as variable as the person approach suggests. In fact, the pilots at Johannesburg behaved, according to the report, in a very similar way to a previous flight crew who were faced with exactly the same contextual conditions a few years earlier, so the behaviour was far from variable it was to some extent predictable. According to the UK Health and Safety Executive (HSE, 2004), before each major accident they investigate they often find a series of similar accidents, near misses and other failures had occurred previously. A completely original accident or incident, whilst uncommon, can happen. The wrong runway takeoff at Lulea was a very uncommon occurrence, and this poses a problem for those devising mitigations. The report into this serious incident (Statens Haverikomission, 2009) found that it was caused by deviations from the crew resource management (CRM) concept, mainly in respect of internal and external communication, thereby placing much of the blame on the flight crew. However, none of the five recommendations concerned mitigations related to the flight crew's actions and the report proposed no changes to flight crew procedures, which suggests that the investigators either did not know what to suggest or that they considered human behaviour unchangeable. The difficulty of defining the role of human error in high reliability organisations (HROs) such as aviation has a long history; in the 1980s Charles Perrow (1984) highlighted the influence of the system in what he called "normal accidents". These accidents were almost preordained by the precise nature of the system. His notion of the influence of *tight coupling* between inter-actions seems particularly relevant to the aviation context. According to Perrow, tightly cou-pled interactions are those that do not tolerate delay, they have invariant sequences and negli-gible slack. Loosely coupled interactions have the opposite characteristics. Probably inad-vertently, airline operations are littered with tight couplings, the consequences of which even those afflicted by them may be unaware. For instance, the previously cited Boeing 747 flight crew who taxied into a building at Johannesburg had briefed their taxi route for in excess of seven minutes whilst they sat at the parking gate, during which time there would likely have been loose coupled interactions between the various activities they needed to complete. In contrast, once the aircraft had left the gate, most of the required activities are tightly coupled; ATC will not expect their taxiways to be blocked by a 747 whilst the FCMs discuss a revised taxying route. Other documented accidents have featured tight couplings related to deteriorat-ing weather at Taipei (ASC, 2002), impending airport closure at Aspen (NTSB, 2002), flight duty time limitations at Tenerife (Netherlands Aviation Safety Board, 1978), commercial pressure at Jakarta (KNKT, 2012), pressure from ATC at Dallas (NTSB, 1989), time limita-tions due to deicing at Birmingham, UK (UK AAIB, 2009) among others. Tight couplings often require actions to be completed in a preset order and most pilots and some insightful outsiders will likely identify with the uncomfortable feeling of having to make decisions and reorganize duties in tightly coupled situations. What they may not appreciate is the increased potential for error associated with tight coupling that Perrow highlighted with several examples from a wide range of high reliability settings. The important point being made here is whether we are to consider the previously cited Johannesburg 747 flight crew's failure to amend their briefing in response to new information during a period of tight coupling as a human error or a system error. The dilemma here is that when the flight crew briefed in a loosely coupled situation their performance was satisfactory but when they were in a tightly coupled situation their performance was substandard so it would not be difficult to argue that the tight coupling resulted in their substandard performance. The relationship between coupling and error as defined up to now is too vague, and essentially subjective, so in the current research some of the specific contexts that give rise to tight coupling are placed under scrutiny. For example, there is some evidence that a significant number of pilots erroneously believe that a takeoff clearance is only ever received when close to the runway in use for takeoff. Serious safety occurrences at Oslo (AIBN, 2010), Singapore (ASC, 2002) and elsewhere have featured this false assumption. There is also evidence from accidents at Charleston (NTSB, 2010c), Bedford, (NTSB, 2015a) and elsewhere, to suggest that some pilots make substandard decisions if they experience an ambiguous situation during the early stages of a takeoff despite there being a prescribed procedure for rejecting a takeoff even at quite high speed. Although these instances may appear at first to be overly specific, this highlights the major distinction between human error causation and the substandard flight crew performance (SFP) causation proposed and explained in this thesis. Whilst *human error* discourse encompasses a wide range of situations and contexts, SFP is intended to identify and categorize specific contexts and situations with a documented link to recurrent accidents and incidents. So whilst the categories traditionally associated with human error in general, such as slips, lapses, mistakes and violations, provide a reasonable framework for human error in general, they are not specific enough for the aviation context. For instance the slip made by flight crews at Lexington (NTSB, 2007a) and Lulea (Statens Haverikomission, 2009) was not just any slip; it was a failure to check their heading prior to starting the takeoff. Any focus upon slips in general would divert attention from this specific phenomenon to the detriment of a complete understanding. Fortunately, despite the complexity associated with aviation, the same phenomena recur in many safety occurrences so it is possible to be very specific about the human limitations being examined. Similarly with violations, there was little evidence in the literature that flight crews violate rules on a regular basis but they do appear to violate the sterile cockpit rule with ease. In her summary of the Lexington accident (NTSB, 2007a, p. 100), the presiding NTSB chairman, Deborah Hersman wrote that "neither pilot seemed hesitant to engage in non-pertinent conversation or demonstrated correcting behavior when the other pilot deviated from sterile cockpit procedures", concluding that "these facts suggest that non-pertinent conversation among company pilots during critical phases of flight was not unusual". In this case understanding the nature of violations in general is far less useful than understanding why this specific rule appears to be so readily violated. In a similar vein, to understand why flight crews sometimes forget to configure the aircraft for takeoff, it is not necessary to review everything that has been written about lapses and mistakes but knowledge of prospective memory, delayed execution and resumption errors is essential. One of the strengths of the SFP construct is its focus upon recurrent phenomena with a proven connection to aviation safety occurrences.

On the basis of the contents of Chapter 2 the following analysis can be made. Commercial aviation is safe but not as safe as it should be given the recent technical advances. It is complex and highly regulated whereas human behaviour can be disorderly and unpredictable. Much of the accident literature is not intended to apportion blame so some factors evade analysis. Statistics relating to aviation safety occurrences do not provide a complete picture of aviation's most serious risks because they do not consider near catastrophes. There are rational reasons why some of these risks may not be highlighted by those with a vested interest. It is not straightforward to understand the vested interests influencing aviation safety. This brief analysis goes some way towards explaining why an accident such as the one at Buffalo (NTSB, 2010a) could occur in the future. One of the aims of the SFP construct is to provide a repository for knowledge that might assist in mitigating the risk of such an occurrence.

CHAPTER 3

SUBSTANDARD FLIGHT CREW PERFORMANCE (SFP)

3.1 CONCEPTUAL OVERVIEW OF THE SFP CONSTRUCT

The purpose of this section is to introduce and describe the new construct which forms the premise of this thesis, SFP. Introducing a new construct into the aviation lexicon is not embarked upon lightly but the intention was to develop a construct that included human behaviour spanning a very diverse range of accidents which shared one feature, the substandard performance of the flight crew. The need to conceptualise SFP was based upon evidence from the reports that often the same human limitation had afflicted flight crews performing quite dissimilar tasks. For instance, two seminal accidents, one a wrong runway takeoff at Lexington (NTSB, 2007a) and the other, a loss of control at Buffalo (NTSB, 2010a) had very little to link them except that both flight crews had performed in a substandard fashion by conducting an unauthorised conversation unrelated to the flight at an inappropriate time. Although both reports emphasised the distraction caused by the non-pertinent conversations (NPCs), neither investigation determined a reason for this seemingly mundane but highly substandard behaviour. This study contends that if these two accidents and the numerous other NPC related accidents had, for instance, been categorised as SFP related accidents from the *verbal factors* basic category and the subordinate category *non-pertinent conversation* (See Figure 3.1 below) the investigations might have had access to more data relating to the underlying reasons for the phenomenon and be better able to identify characteristics of the aviation system that might have contributed to the accidents. The rationale for this contention is that although the two accidents under discussion could hardly have been less similar, the content of the NPCs conducted was remarkably similar, with comments about changing jobs, career progression, family life, other airlines and industrial matters. This pattern of behaviour and its correlation with accidents is an example of what the SFP construct is intended to illustrate. Although the superordinate category SFP may seem unnecessarily vague it is intended to encompass approximately 60% of all fatal airline accidents worldwide according to the CAA statistics so it cannot be too specific about what constitutes SFP. It is when the basic concepts are introduced that the model becomes more focused. As the SFP construct is still in its development only three basic categories have been chosen for experimental research in this study (spatial, contextual and verbal) although it is likely that all levels of the hierarchical structure could grow with time. It can be seen from Figure 3.1 that each basic conceptual category has subordinate conceptual categories, for instance the subordinate verbal factors examined in this research are non-pertinent conversation and unclear communications.

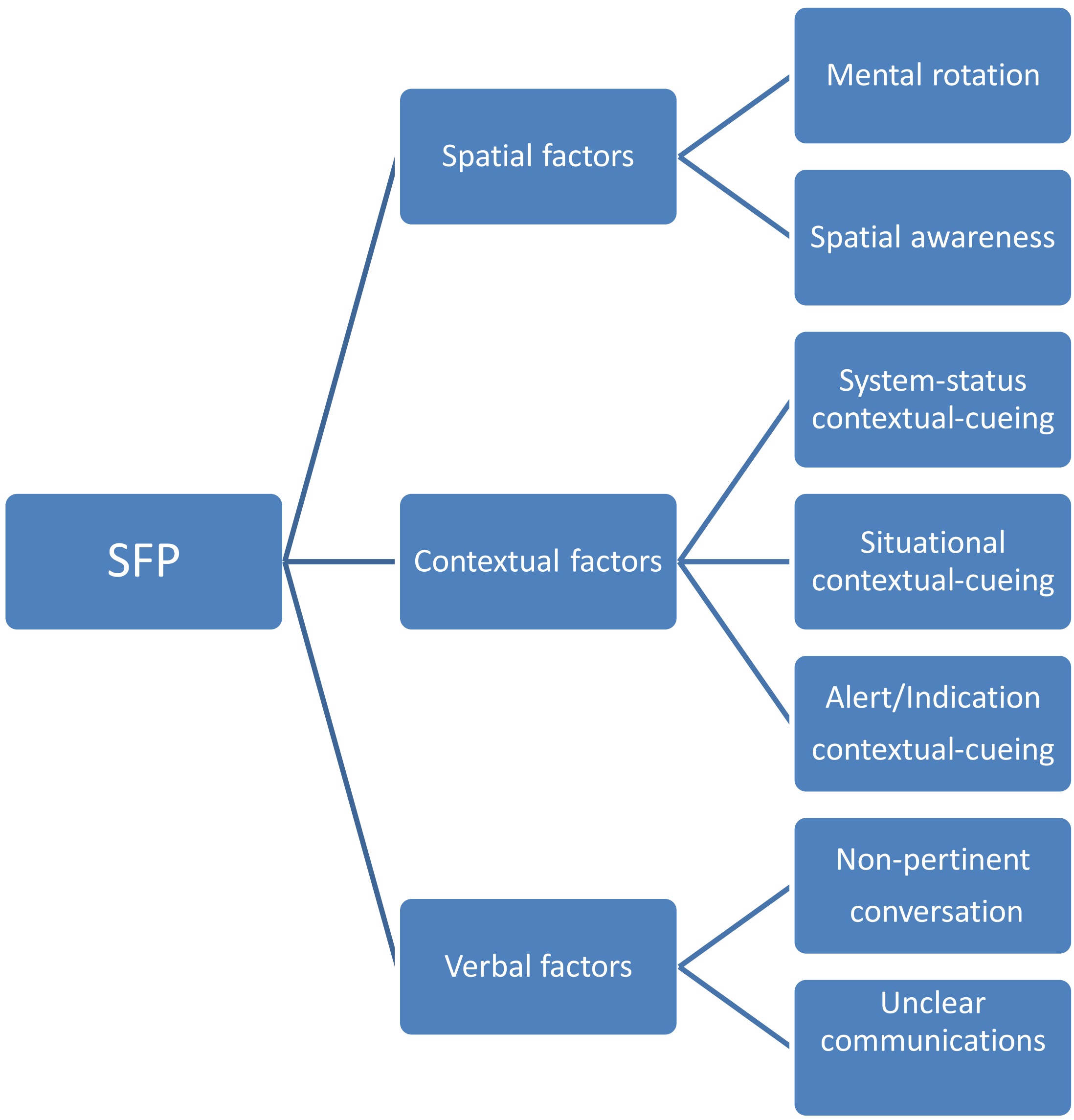


Figure 3.1: A conceptual model of the SFP construct illustrating the research outlined in this thesis.

Once fully developed, the SFP construct is intended to act as a repository for knowledge relating to specific categories of SFP related events. In order for this to happen there needs to be a clear understanding of what constitutes SFP and what does not. The list below outlines what constitutes SFP based upon accounts from the literature:

- **SFP occurs when a flight crew performs at a level inconsistent with their training and qualifications**

The aviation occurrence literature indicates that regulators, operators, air traffic controllers and a range of other members of the safety system have an expectation of how flight crews should perform. Accident investigations have found that flight crews who meet or exceed regulatory standards during regular recurrent checks have at the time of the accident performed below an acceptable standard. This was the case in accidents at Buffalo (NTSB, 2010a) and Lexington (NTSB, 2007a) and indicates that satisfactory performance in recurrent checks is not an assurance of satisfactory everyday performance.

- **SFP can occur during both normal and non-normal situations but is rarely caused by a malfunction**

The definition of *normal* is problematic because what is normal is a matter of degree. In an accident at Cali in Columbia (ACRC, 1996) the flight crew received a change to their route which although unexpected, they were at liberty to decline. The judgment about whether to accept such a clearance is one that any competent flight crew is expected to be able to make without compromising safety. The NASA ASRS database indicates that unexpected or late changes to the route can cause problems for flight crews due to the distraction caused by updating their flight management computers and accessing charts. There is a persistent narrative in such reports along the lines that air traffic controllers should be more aware of the workload increase that occurs as a consequence of short notice changes. Although the flight crew invariably bear much of the blame when a CFIT accident such as the one at Cali occurs, the SFP construct examines the role of other parties involved such as air traffic controllers. Whilst the pilots retain overall responsibility for the safe conduct of the flight it would be misleading not to consider in some detail the role of the controller in the FCMs' performance. In a very similar accident a British flight crew approaching Tenerife (UK AIB, 1981) received an ambiguous holding instruction at very short notice at a radio beacon with no published holding pattern. Multiple factors can influence how normal a situation can be considered. The context in which the Cali accident occurred is one which any flight crew would be expected to handle, whereas although the Tenerife accident was very similar, the air traffic controller's actions were far more instrumental in the accident due to the extraneous cognitive load imposed by the unreasonable time constraint and the absence of any published procedure. Thus the definition of normal is open to interpretation but on balance, both these accidents fall into the SFP category because it would be reasonable to expect a competent crew to deal with such matters.

Just because an aircraft experiences a malfunction it is unsound to necessarily assign the cause of an accident to the malfunction. In 1995 the report into a CFIT accident involving a Dash Eight commuter aircraft in Palmerston North, New Zealand (TAIC, 1995) concluded that despite the flight crew having experienced a problem with the landing gear extension, four of the five causal factors were attributed to the flight crew's actions and none to the malfunctioning landing gear. It must be emphasised that most conceivable malfunctions are recurrently trained to proficiency in the airlines so it is completely reasonable to expect flight crews to perform at a standard consistent with their training and qualification in such circumstances.

- **Weather conditions influence SFP but do not cause it**

Adverse weather should not cause airliners to crash. The reason for this assertion is that if the weather is so bad that it poses a safety risk, a competent pilot should not be attempting to fly there. Airports and their related procedures vary considerably in the risks associated with them. Certain airports require special qualification in order to mitigate the associated risks. The objective of such procedures is to maintain the risks at an acceptable level although they are never as safe as more straightforward airports. Although airlines do expect their qualified flight crews to operate to high risk airports, there is little evidence that operators encourage rule breaking. An accident at Aspen was an example of a flight crew failing to comply with the procedures required for safe operation at a challenging airport. Notably the associated report (NTSB, 2002) cited the weather as a contributory factor. Given that operators' special procedures are intended to mitigate the risks associated with the weather it is misleading to cite weather as even a contributing factor. Even if the weather is reported as being suitable, every pilot should know that it remains the decision of the FCMs to decide whether a safe landing can be achieved. If they disregard the procedures, the weather is no more than a side issue, with SFP the main cause. In general, the use of extreme weather as causation for accidents is misleading because a trained and licenced flight crew is expected to exercise skill commensurate with their role when deciding whether to operate in given weather conditions.

- **External factors influence SFP but do not cause it**

The accident at Aspen, SFP partly resulted from external pressure. According to the NTSB report (NTSB, 2002, p. 41) a contributing factor was "*the pressure on the captain to land from the charter customer and the airport's night time landing restriction*". This accident was a charter but elsewhere in this thesis there is a discussion about how airline flight crews are subject to similar pressures due to the commercial climate and the sense of feeling responsible for disruption resulting from factors often outside their control. An important lesson from the Aspen accident is that even those on the periphery of the aviation system can be implicated in instances of SFP without any knowledge of the adverse effect their actions invoke. It has been successfully argued in court that the actions of an outside agency can be responsible for an accident that at face value appears to be SFP. This was the case in a sightseeing accident near Mount Erebus, Antarctica (TAIC, 1979) where the airline navigation department provided incorrect navigation data contributing to CFIT. It is notable that this accident was initially attributed to *pilot error*, a decision reversed in the high court. This accident highlights the difficulty of being dogmatic when apportioning blame because the Erebus transcript clearly indicates that the FCMs were uncomfortable with the actions they were taking in advance of the crash. In most conceivable cases a flight crew who crashed into terrain after expressing doubt about their terrain clearance would be considered to have performed at a substandard level of skill despite any extenuating circumstances prevailing. There is scope in the SFP construct to include an abstract factor such as the ambiguity of a particular type of operation as a category for research. For instance, the literature indicates that flights of an ambiguous nature such as sightseeing flights at Mount Erebus, Antarctica (TAIC, 1979) and Ketchikan, Alaska (NTSB, 2015b), demonstration flights at Basle (BEA, 1990) and Jakarta (KNKT, 2012) and VIP flights at Smolensk (Interstate Aviation Committee, 2011), and Dubrovnik (Flight Safety Foundation, 1996) all carry an increased risk of SFP which, as far as is known, is not made explicit anywhere in the literature and is almost certainly not known by stakeholders such as the passengers. Although each of the foregoing accidents was an instance of CFIT they each possessed ambiguous characteristics that distinguished them from CFIT accidents in general. The SFP construct has potential to home in on the factors that influence very specific types of accident and to identify and examine any recurrent factors.

- **Industrial relations factors can encourage SFP and may be part of its cause**

SFP and professionalism are closely linked; recently the focus on pilot professionalism has become sharpened due mainly to the two seminal accidents cited at the start of this section. This study found evidence of career dissatisfaction among certain flight crews and this, to some extent, encouraged SFP. Whilst citing industrial matters as a serious factor in the occurrence of SFP may seem an abstract concept, there is considerable cross-cultural research suggesting a link between working conditions and quality of work performance from a range of occupations, such as doctors (Baldwin et al., 1997) and teachers (Hakanen et al., 2006). Each of the pilots involved in accidents at Lexington (NTSB, 2007a) and Buffalo (NTSB, 2010a) were considered to be competent by their employer and their peers so their substandard performance was uncharacteristic; later in this thesis a model is proposed in which SFP might occur without conscious awareness in response to poor working conditions. So whilst the overall tone of this explanation of SFP has been that the flight crews are normally expected to perform to a uniformly high standard regardless of external factors, the individuals involved are not robots so the interaction between prevailing working conditions and the individual must be subject to scrutiny. Influential bodies such as the NTSB have highlighted the need for a focus on pilot professionalism by placing it on their “ten most wanted improvements” list in recent years but at present there appears to be no co-ordinated means of collating the emerging knowledge on the subject. In the future the SFP construct could incorporate basic categories such as *professionalism* or *organisational influences* so that accidents like those at Buffalo and Lexington are examined in terms of the wider influences that may have contributed to the SFP. This would also serve as a repository for such information accessible to managements and regulators so that they could not claim that the issue had not been documented. As the SFP construct is under development only three basic SFP categories were examined in this research, verbal factors, contextual factors and spatial factors.

3.2. RATIONALE FOR SELECTING THE THREE BASIC SFP CATEGORIES FOR EXAMINATION

This research emerged in response to two airline accidents, one at Buffalo and the other at Lexington that appeared to encompass many of the features of contemporary airline accidents. These emblematic accidents both occurred in the USA but the research conducted for this study indicated that remarkably similar accidents and incidents had occurred around the world. Airline flying has undergone rapid change in recent years, and although there is much continuity, it was a priority of this research to address issues that affect the aviation system today. The overarching issue that has been tiptoed around for decades is that on occasions pilots perform below an expected standard; the substandard flight crew performance (SFP) construct was conceived to better understand some of the reasons that this occurs. In both accidents referred to above, the flight crew members (FCMs) had been conducting an unauthorised conversation which is likely to have distracted them and precipitated the accident. In the Lexington accident the FCMs had lost awareness of both their position on the airport and their orientation. In the Buffalo accident the FCMs lost track of their proximity to the airport during final approach and needed to decelerate quickly, which they had not adequately planned for. In both cases there was a breakdown in communication between FCMs. In the former, an expression of doubt voiced by one FCM was not made explicit, and in the latter a critical configuration change occurred without any communication between FCMs. A review of similar accidents and incidents revealed that certain types of error often occurred when several contextual factors came together, which prompted a focus on the influence of context in aviation safety. The Lexington and Buffalo accidents acted as a springboard to examine several aspects of human activity that in the researcher's opinion were not adequately explained in the literature related to those accidents. Two important questions addressed in this research were actually posed by the NTSB in the wake of the Buffalo accident; why do pilots break the sterile cockpit rule, and is this normal behaviour in the flight deck? In terms of unclear communication, the UK AAIB was also unable to explain why an air traffic controller at St Kitts (UK AAIB, 2010a) did not challenge an incorrect decision by a flight crew, stating that it was "possibly a result of insufficient human factors and resource management training". The verbal strand of this SFP research has potential to provide more detailed explanations than those in the report.

Similarly, the NTSB report into the Lexington accident highlighted deficiencies in the flight crew's compliance with the sterile cockpit rule and their briefing content but "could not determine why the flight crew stopped the airplane at the wrong stop short line and then attempted to take off from the incorrect runway" (NTSB, 2007a, p. 75). This comment effectively asked two questions, firstly how the FCMs could not detect such a gross directional error and secondly, why they failed to comply with procedures intended to mitigate this risk? The spatial awareness strand of the current study examined the relationship between spatial awareness tasks and cognitive load and outlines some human limitations that may have resulted in the flight crew's substandard performance in this instance. Although briefly mentioned in the Lexington report, very little emphasis was placed upon the influence of the first officer's previous experience of the airport's lighting deficiencies. This represented a contextual cue that would form part of a schema-based representation of what the runway would be expected to look like when lined up for takeoff. This type of expectation was also mentioned by the captain of the St Kitts flight crew (UK AAIB, 2010a, p. 23), so this research sought to operationalise the concept of contextual cueing as it relates to aviation safety. Section 3.3 uses the example of the Lexington accident to illustrate how the verbal, spatial awareness and contextual cueing research strands apply to a real life SFP-related accident.

3.3 THE ANATOMY OF AN SFP INSTANCE.

This section uses the example of the Lexington (NTSB, 2007a) accident to demonstrate how the research questions outlined in the next chapter directly address a current SFP related occurrence. Figure 3.2 below illustrates the sequence of events as the flight crew taxied to the runway in the dark (their route is marked by red arrows). The FCMs were intending to use runway 22 but attempted to depart from runway 26 and impacted a mound killing 49 people. An explanation of the relevant factors at each position on Figure 3.2 appears below.

Figure 3.2: Sequence of events at Lexington (image adapted from NTSB, 2007a).

At position A the FCMs conducted a detailed conversation during the pre-flight preparations that continued whilst taxiing to the runway. According to the NTSB (2007a) this non-pertinent conversation more than any other factor distracted the flight crew from lining up and taking off from the correct runway. At position B the FCMs thought they were at the hold short line for runway 22 when they were in fact at the hold short line for runway 26. The loss of positional awareness was in part due to inadequate briefing but the flight crew had clearly lost directional awareness at this stage because there is an angular disparity of 90˚ between the two holding positions. It is not known whether they had started to detect their disorientation as they lined up on the runway but their performance deteriorated inasmuch as they omitted to check the runway direction or to respond to cues present on their displays that would have alerted them to their error. The NTSB (2007a) commented on this omission but offered no explanation for these lapses. At position C the FCMs missed several cues that they were at the wrong position. The NTSB report commented on several contextual cues that may have been relevant. The presence of runway markings and a white centreline and side stripes ahead of the airplane would have facilitated the captain's perception that the airplane had arrived at the hold-short line for runway 22, even though the airplane was actually at the hold short line for runway 26. In addition, the angle from the runway 26 hold short line on taxiway A to runway 26 was the same as the angle from the runway 22 hold short line on former taxiway A (north of runway 8/26) to runway 22. The investigators also commented that both lighting and painted markings present in the visual scene could have supported the captain's perception that the airplane had arrived at the departure runway. Furthermore, the first officer had previously commented upon aspects of the lighting that might have supported the unusual lighting configuration the FCMs encountered as they attempted to depart from the wrong runway. The captain of an Aeroflot Airbus which took off on a taxiway at Oslo airport (AIBN, 2010) also reported that he may have been similarly influenced by aspects of the runway markings he had experienced earlier when he landed. At position D the first comments that signified all was not well were made but they were unclear. The Lexington accident could have been prevented if either pilot had clearly communicated their doubts about the takeoff. The extract below is a comment relating to the lighting at the commencement of the takeoff.

> *"The first officer stated, "[that] is weird with no lights," and the captain responded, "yeah," 2 seconds later"* (NTSB, 2007a p. 6).

Where comments are made that would not normally be expected at a critical phase of flight it usually means something is wrong because if everything was right it would not be necessary to speak. The Lexington captain did not identify the doubt expressed by his colleague because it was attenuated in nature. The current research operationalises this type of unclear communication by identifying recurrent instances from the occurrence literature and proposing explanations for their occurrence. Accidents at Tenerife in 1977 (Netherlands Aviation Safety Board, 1978), Washington in 1982 (NTSB, 1982) and St Kitts in 2009 (UK AAIB, 2010a) all involved unclear communication.

CHAPTER 4

THE METHOD OF ENQUIRY EMPLOYED IN THIS RESEARCH

The method of enquiry was firmly ethnographic; the qualitative data used for each of the research strands was derived from official accident and incident reports. These reports were chosen on the basis of the researcher's subjective assessment of their suitability as examples of SFP. The conversation questionnaire and its associated unstructured interviews generated qualitative and quantitative data which would have been meaningless without the contextual insights gained from the narrative in the reports. Although the spatial awareness strand used experimental methods and produced quantitative data for statistical analysis, the study also considered convention and practices unique to aviation. For instance, whilst a human cognitive limitation may have resulted in the Buffalo accident flight crew losing positional awareness, this study's ethnographic orientation provided explanations relating to the institutional practices that facilitated the cognitive limitation. The contextual cueing experiments were designed in response to qualitative data in the reports but could only be adequately researched by conducting experiments and generating quantitative data. However, the institutional procedures and how they are enacted by the pilots is often mentioned in reports so the institutional procedures of the airline context were always at the forefront of enquiry in this research. In the runway accident at Lexington (NTSB, 2007a), factors as disparate as a distracting conversation, loss of positional awareness, loss of directional awareness, unclear communication and misleading environmental cues, among others were evident. The reader could be forgiven for finding it difficult to reconcile a link between such diverse topics but that is exactly what was necessary in order to achieve this research's aim of developing a comprehensive repository for SFP related knowledge. During this research it became clear that on occasions, what appeared to be a robust safety system was breaking down because of an unrealistic expectation of uniform human performance. Evidence of this was found in cases where both operators and regulators expressed surprise that a pilot who had passed recurrent checks could nonetheless perform below an acceptable standard on a given day (NTSB, 2010a, pp. 110-113). Similarly, there was an unrealistic expectation that because a rule was in place, pilots would always comply with it (NTSB, 2010a, p. 45). In the face of evidence from the reports indicating that an expectation of uniform human performance was unrealistic, the question of how to reduce flight crew-initiated accidents and incidents became a complex one where many of the assumptions that formed the foundation of the aviation safety system appeared unsound. For instance, if NPCs are a persistent factor in airline accidents, the rule prohibiting them is ineffective and the reasons they occur need to be examined. The current perspective from the NTSB and FAA is to conflate NPCs with pilot professionalism[vi] but this thesis will demonstrate that there may be aspects of the institutional context and their human make up that are unlikely to be unearthed by examining the pilots' actions in isolation. Perhaps the reason that in the four decades since NPCs emerged as a contributory factor in airline accidents so little progress has been made in reducing their incidence is the failure to acknowledge the disorderly nature of human behaviour in what should be a highly regulated environment. The accident reports provide ample evidence of this disorderly behaviour; for this reason the current research adopted an ethnographic method of enquiry, which in contrast to many of the reports, took more account of the people involved, their interests and views, and the limitations imposed by the context within which they were working. For instance in the 1970s one flight crew at Charlotte (NTSB, 1975a) were discussing a fairground ride they thought they could see through the top of the cloud bank just before they crashed, and more recently a Russian pilot (KNKT, 2012) was conducting a sales patter in the moments before a CFIT accident. Although both these accidents were directly caused by a failure to follow procedures, the associated reports contained almost no analysis of the institutional and situational context that facilitated the infringement. This tendency to gloss over the underpinnings of behaviour was also evident in the report into the Buffalo (NTSB, 2010a) accident, in which the assigned probable cause was the captain's incorrect response to the stall warning which led to an aerodynamic stall. The view that the pilots' actions were the root cause of this accident loses some of its force when we discover that several similar occurrences have afflicted other flight crews flying the same type of aircraft both before and since the Buffalo accident. The fact that pilots who appear to perform satisfactorily most of the time but in a context that has prevailed in previous similar incidents have performed in a substandard fashion, surely requires a detailed consideration of that context. In fact, several incidents very similar to the Buffalo accident have occurred in locations as diverse as the UK, Australia and the USA so to suggest that the problem lies squarely with these pilots on that night at that location represents a reductionist perspective. The incidence of several stall related occurrences in the same type of airliner as was involved at Buffalo even prompted a review of all such incidents and accidents in Australia (ATSB, 2013), of which there were several. However, despite evidence that in two of the incidents (one in 2008 and one in 2011) that the FCMs were using the same non-standard procedure to decelerate as the FCMs at Buffalo in 2009 had used, and in one case had made an identical mistake in setting their speed reference switch, there was no attempt to cross refer the Australian experience to the fatal accident in Buffalo. Given that it is implausible that all operators of this type of aircraft would not have at least some knowledge of the Buffalo accident it is disquieting that the most significant accident was omitted from analysis in the review. This highlights how aviation's stakeholders can act as an impediment to progress. The Buffalo accident was among the highest profile fatal accidents in recent history so it is perhaps understandable that interested stakeholders might seek to de-emphasise the similarities between their incidents and that accident. Airlines in general, place a very high value upon their perceived safety record but this may be achieved at the expense of disseminating complete information to the wider community. Charles Perrow (1984) distinguished between *normal accidents,* those which were unpredictable and just a fact of life, and those that safety systems have a responsibility to address on the basis of previous experience. Whilst the uncommon nature of an airliner stalling on final approach, as was the case at Buffalo, might qualify the accident as a “normal accident”, similar near accidents that followed certainly do not and therefore should be reported in the most transparent fashion. The foregoing example highlights the need to understand who the interested parties are and what they have at stake. In a case such as just outlined, the manufacturer, the operator, the pilots, the procedure designer, the regulator and a host of other parties might be interested. Given that the largest airliner manufacturer in the USA employs almost 200,000 workers and its counterpart in Europe almost 140,000 it is easy to see how widely the influence of adverse publicity might be felt. This spreading influence sometimes makes it difficult to identify who has ownership of a problem. In the hypothetical instance of a major manufacturer encountering difficulties resulting from bad publicity following an accident, the government has an interest in protecting the country’s economy so could conceivably be forced into becoming a stakeholder in protecting the company’s reputation. In general, a tarnished safety record or stories of low pay and conditions for their pilots do not seem to discourage passengers from using an airline, which indicates they accept that they are in safe hands when they fly. This suggests that they do not expect to be the owners of their own safety when they board an airliner. Although this may appear to represent the travelling public as naïve, it highlights that whether one is a passenger, a CEO of an airline, a regulator or any other stakeholder there will be environmental constraints that limit the ability to achieve absolute safety. Aviation safety viewed from the perspective of the multiple reports reviewed for this study emerged as a complex system in which many of the influences were implied rather than explicit which meant that before any progress could be made it was necessary to organise the safety system into a conceptual framework that reflected the disorderly nature of what has been described. It was essential to gain an understanding of how the system is viewed by those who are detached from the frontline but nonetheless have to make and implement policies. The reports provided valuable insights into how pilots and those who work with them view their responsibilities regarding aviation safety. A realistic worldview of aviation safety can be obtained from some of the discourse in the reports. It is possible to infer from some of this discourse what individuals' motives might be and how their activities might be enabled or constrained. All of the worldviews expressed in this research were based upon narrative comments from the various reports, such as the persistent narrative relating to pilot fatigue evident from airline managements in the aftermath of an accident (See NTSB, 2010a, p. 49 for a comment related to fatigue from the Buffalo accident airline's assigned regulator) or the surprise expressed when a pilot fails to perform to an expected standard. The narrative is often one of justification and distancing from responsibility along the lines that the flight crew should have known not to do what they did (See NTSB, 2010a, p. 50 para 1.17.6). The comment below was made by Delta Airlines' chief pilot in response to criticism by the FAA relating to lack of organisational discipline in the wake of the Dallas accident.

"Many elements of our procedures are left to the discretion of the captain."
(NTSB (1989, p. 76).

The comments and behaviours outlined in reports provide the best available insight into how those within the aviation safety system view the world and it is not always as one would expect. We find air traffic controllers who are satisfied with passing an instruction but apparently not concerned with whether it has been understood (UK AAIB, 2010a, p. 21). We find pilots who think that they can apply their own interpretation to rules (See ANSV, 2004, p, 112), and airport authorities who fail to implement rules and recommendations despite evidence of a continuing risk to safety (See ANSV, 2004, pp. 162-3). In the wake of the Buffalo accident (NTSB, 2010a) accident there was a debate about pilot professionalism centred on the young first officer's decision to fly when she was unwell and to commute a long distance before the flight. The method of enquiry adopted by this research prompted the researcher to take an objective view relating to who owns such problems. Is it the young inexperienced pilot who needs a job, the airline who sees an opportunity for a cheap, compliant pilot, or the regulator, who must be able to see the potential for the compromises in professionalism that were evident in the way the Buffalo accident flight crew flouted the rules related to fatigue management? The foregoing examples are all from the literature and they are intended to illustrate how this study was able to elevate the worldview of aviation from intuition to a researchable phenomenon. Once the various stakeholders and their interests have been identified it becomes easier to propose transformations to the system but they must be feasible within the prevailing constraints. It helps no one if the airline is forced to increase salaries and ceases to trade as a consequence, but if it cannot pay sufficient to ensure a safe operation perhaps it should not be operating in the first place.

4.1 THE MODEL OF SFP RELATED ACCIDENT CAUSATION UTILISED IN THIS STUDY

This study identified the following problem in relation to aviation safety:

PROBLEM STATEMENT:

The occurrence literature indicates that a significant proportion of aviation accidents feature elements of SFP.

The literature also indicates that many of these accidents involve:

- Loss of spatial or positional awareness
- Confusion or distraction related to verbal communication
- Flawed decision making based upon contextual cues

The literature indicates that these occurrences are characterised by the factors illustrated in Figure 4.1 below.

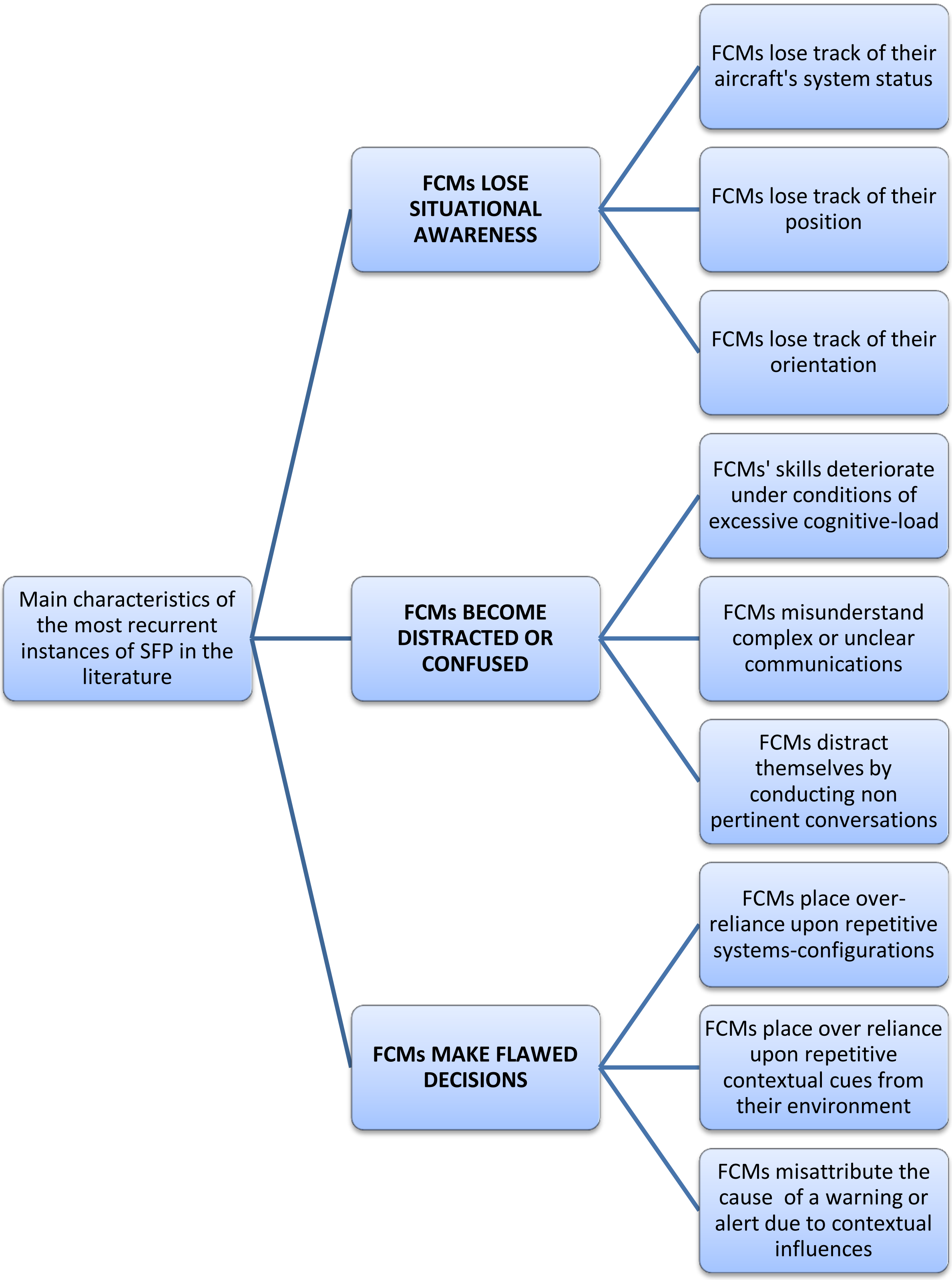


Figure 4.1 The main characteristics of the most recurrent instances of SFP in the literature.

4.2 A WORLDVIEW OF AVIATION SAFETY

This section outlines a worldview of aviation safety by comparing the systems-approach to aviation safety with the real world; it is important to explain what is meant by a systems-world approach. James Reason is among several experts who have examined aviation safety in terms of a systems-approach where the human causes of an accident are distributed very widely both within the system as a whole and often over several years prior to the actual event (Reason, 1995). Although the current UK CAA Safety Plan (UK CAA, 2015) refers to aviation safety as a system and highlights current initiatives relating to pilot performance, this research was unable to locate any explicit reference to exactly what the regulator and the other influential stakeholders in aviation safety expect from their flight crews. The systems-world used in this research is based upon narratives in the reports. For instance, the Buffalo report (NTSB 2010a, p. 89) concluded that "the captain's response to stick shaker activation should have been automatic, but his improper flight control inputs were inconsistent with his training". This narrative highlights that once training has been delivered there is an expectation of performance that was not met on this occasion. The Lexington accident report (NTSB, 2007, p. 43) mentioned that there was an expectation that the flight crew would confirm their heading before commencing takeoff even though it was not an action required by the operator at the time. Neither the Buffalo nor Lexington reports could explain why the procedural non-compliances evident in both accidents occurred. In the Buffalo report a manager stated that he did not know how many of his airline's pilots were commuting but he did prohibit flight crews from sleeping in the crew room (Ibid, p. 50), which suggests he was aware of the possibility that such an infringement of rules was possible. These are the types of narrative that form the systems-world perspective that is compared with the real-world in Figures 4.2 and 4.3. Each of these narratives originated from an interested party in aviation safety; in section 4.3 all the interested parties and their possible motivations are outlined.

Based upon the literature review conducted for this research the worldview of aviation safety in Figures 4.2 and 4.3 is proposed.

Figure 4.2 A systems-world perspective on aviation safety.

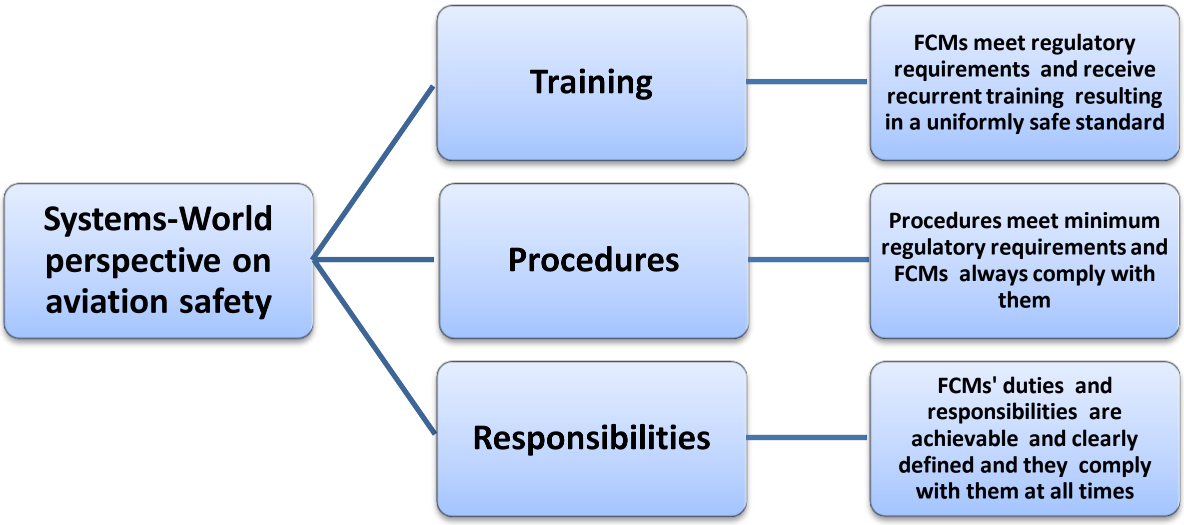
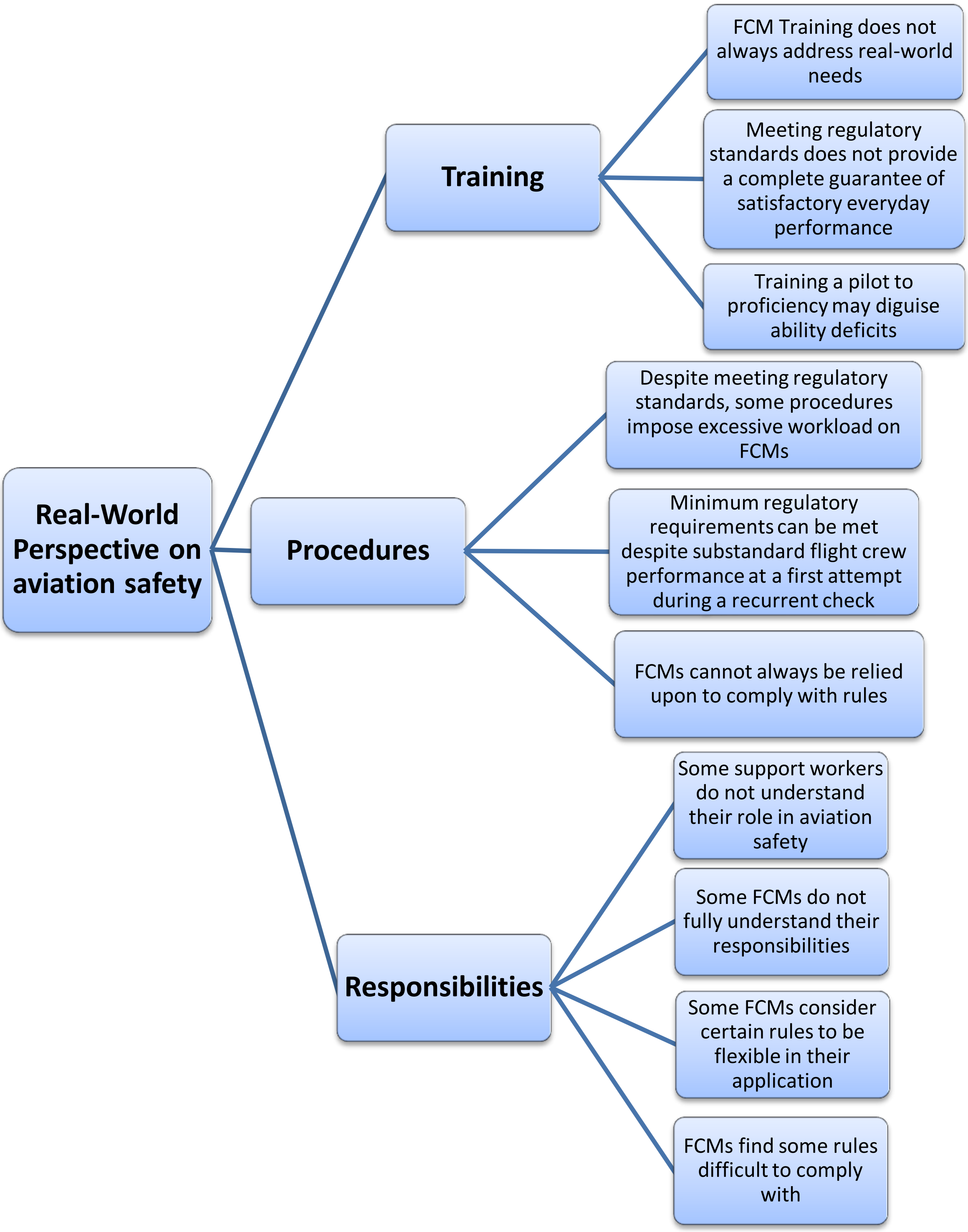


Figure 4.3 a real world perspective on aviation safety.



Once the problem had been defined and the prevailing worldview had been identified, the next step was to identify the consumers of aviation safety (the customers) and those who provide aviation safety (the actors). Because in the aviation context customers and actors sometimes merge it was decided in section 4.3 to refer to them as stakeholders and examine their role both as customer and actor where appropriate.

4.3 AN EXPLANATION OF THE VARIOUS STAKEHOLDERS IN AVIATION SAFETY

An essential stage of this research involved defining the role of the stakeholders who influence the system. Unlike some systems, in the aviation safety system many of those involved are both customers and actors, for instance, pilots both provide safety and rely upon others to provide a safe environment for them to work in. Managers are customers of the flight crews but they are also actors who exercise influence over their activities. The occurrence literature suggests that actors sometimes fail to understand the role they play in aviation safety. Based upon the literature, this section and its subsections below identified who aviation's stakeholders are and what motivates their activities.

4.3.1 THE TRAVELLING PUBLIC

Qualitative research conducted by the UK Civil Aviation Authority (CAA, 2015) indicates that the travelling public is not excessively influenced by safety and security concerns. They also found that passengers were reluctant to engage with safety matters, mainly because such engagement might make them feel less secure when flying. The CAA's quantitative research found that 36% of those passengers who had previous experience of flying said they didn't think much about safety. 58% of those surveyed considered that air travel is safer than other modes of transport and 54% said that safety standards are as high as they can be. In general, the travelling public showed no strong desire for more information related to safety with only 39% stating they were open to such initiatives and 21% stating they would not be interested in receiving such information. The fact that customer service ranked higher than safety concerns confirms that the travelling public assumes that safety is taken care of by someone else. There was also little interest in knowing which airlines were safest or least safe, with a tendency to assume that someone must be ensuring that unsafe airlines were never encountered. Passengers also showed little concern relating to travelling on a "leased in" aircraft but notably, there was an assumption that regulatory oversight and professional standards could be assumed in such cases. Overall, the passengers surveyed were happy to devolve almost all aspects of remaining safe to others and to avoid engaging with safety issues in case they were put off flying.

4.3.2 THE FLIGHT CREW

Although accidents at Lexington (NTSB, 2007) and Buffalo (NTSB, 2010a) among others have called pilot professionalism into question there is strong evidence that pilots have much to benefit from a safe operation. Their personal safety is an obvious factor given that in both the accidents above, the pilots lost their lives or were seriously injured. Where they do survive, they are likely to encounter difficulties obtaining work again even if they are fit. This can also be the case if no blame attaches to the pilot concerned as was the case with a captain involved in a British Airways Boeing 777 landing accident at Heathrow (UK AAIB, 2010c). The reports indicate that operators sometimes seek to distance themselves from responsibility for their pilots' actions so an individual pilot may be legally liable. The psychological impact of even a serious incident can profoundly affect a pilot; in 1990 a British Airways Boeing 747 captain was found guilty of "negligently endangering an aircraft and its occupants" and received a substantial fine in lieu of a prison sentence. The pilot concerned resigned shortly after the verdict and committed suicide in 1992 (Connett, 1992). There is much evidence that pilots engage with flight safety, as evidenced by the 715,000 voluntary reports received by the NASA ASRS in its 30 year history. Decades of reports show that pilots are proactive in offering their opinions regarding procedures or systems that they perceive as being deficient. There are numerous documented instances of pilots reporting deficiencies in aircraft design in advance of an accident, as was the case with the 1973 Trident accident at Staines (UK AIB, 1973). In some of the accidents examined for this research it was clear that had the pilots been aware of a previous similar occurrence they might have avoided an accident. Pilots are taught how to manage threats and errors but they must be made explicit by those who possess the relevant information. Pilots have every incentive to maintain high standards; the reports showed that career progression was a major topic of discussion among flight crews. During the investigation into the Buffalo accident (NTSB, 2010a, p. 116) the airline's senior representative said that had he been aware of the captain's history of underperforming he would not have qualified for employment by the airline. Pilots are aware that any evidence of poor performance or noncompliance represents a serious impediment to future advancement. Nonetheless, much of the current research involves pilots who have broken one rule or another. There was no evidence that pilots were habitual rule breakers so it is possible that the pilots concerned simply did not recognise their behaviour as unacceptable or they felt able to interpret the rules according to a different standard than the operator.

4.3.3 THE AIRCRAFT MANUFACTURER

When an aircraft crashes, one of the most frequently posed questions involves the safety record of the type of aircraft. The nightmare scenario for a manufacturer is that an accident occurs during development. Sales of the innovative Comet airliner were seriously affected by accidents in the early days of service and this arguably led to its commercial failure. Shares in Airbus fell immediately after the recent crash of a new military variant in Seville (Spence, 2015). Even when the aircraft is clearly not at fault as was the case in a recent accident in the Pyrenees the manufacturer's share price is likely to fall in response to an accident. An accident involving an aircraft in development can result in a loss of confidence in the aircraft with resultant cancelled orders as was the case in the immediate aftermath of an accident involving a Sukhoi Superjet at Jakarta (KNKT, 2012). In this case the reputation of the aircraft has restored and few orders were lost. Because aircraft manufacturers are usually enormous financial undertakings it is to be expected that lawsuits tend to be directed towards them. A recent accident involving a Boeing 777 at San Francisco (NTSB, 2014a) has resulted in some of the passengers attempting legal action against Boeing despite the fact that the aircraft performed in line with its technical specification. The manufacturer is often involved in almost every stage of an airline's operation from providing training, to supplying manuals so it is difficult for them to avoid some fallout from an accident. Manufacturers can also benefit when a deficiency is present in the safety system by devising mitigations. The Honeywell Corporation is estimated to have earned close to one billion dollars revenue through the development and sales of EGPWS technology. A similar revenue stream is likely to result from the introduction of electronic flight bag (EFB).

4.3.4 THE AIRLINE OPERATOR

An accident is quite likely to signal the end of an airline. A Cypriot operator failed within one year of an accident near Athens despite having renamed the airline. A famous case of an airline failing due to its safety record is that of Adam Air in Indonesia. Adam Air experienced no fewer than four serious accidents between 2006 and 2008 and was closed down by the regulatory agency in 2008. Such airlines are unlikely to be the employer of choice for the best pilots so there is likely to be a continuing issue concerning the calibre of pilots in such airlines. Adam Air provides a clear indication of what results when an airline fails to comply with regulations. Colganair, the airline involved in the Buffalo accident, was renamed one year later and subsequently lost most of its connections with major airlines. It ceased operations two years later. The Buffalo accident resulted in multiple lawsuits against Colganair. Although much of the criticism in the Buffalo accident report was directed towards the pilots, the airline is usually considered to share the responsibility for their flight crews' actions.

4.3.5 SUPPORT WORKERS

As far as is known, the role of support workers in securing flight safety has not been considered in any depth before. In a serious takeoff accident at Auckland (TAIC, 2003) the presence of the station manager in the flight deck during preparations was relevant:

"The second first officer would normally cross check the bug card data and computations, but in this instance he stowed the Airport Analysis Charts without verifying the information recorded on the bug card. At the time he was occupied explaining the departure delay to the operator's station manager". (TAIC, 2003, p. 4)

In interviews after an accident at Birmingham, Alabama (NTSB, 2014b, pp. 53-61.):

"...the accident dispatcher stated that he did not want to "insult" the captain by informing him of what he viewed as an unavailable approach to the runway..."

An air traffic controller at St Kitts (UK AAIB, 2010a, p. 21) rationalised his failure to inform a Boeing 777 flight crew that they were lining up for takeoff at the wrong position as follows: *"...although it appeared to be a short takeoff run, pilots are aware of their own aircraft's performance. Although he had seen many smaller local aircraft start their takeoff rolls from Intersection Bravo he had not seen a Boeing 777 do this. Additionally he said the misidentifi-*

cation of taxiway bravo for alpha was, on average, a weekly occurrence and it appeared to be happening mostly to overseas operators"

Despite the above testimony the air traffic controller elected not to advise the pilots.

At Kegworth in the UK the need for coordinated action between flight crew and cabin crew was highlighted:

"Had some initiative been taken by one or more of the cabin crew who had seen the distress of the left engine, the accident could have been prevented" (UK AAIB, 1990, p. 106)

At Dryden (Canadian Commission of Enquiry, 1992) both cabin attendants and positioning flight crew did not speak up when they saw an ice accumulation on the wing of the aircraft they were about to depart in.

An accident at Aspen highlighted how even a customer who is allowed to get too involved in the operation of the aircraft can be implicated in an accident:

"When told about the possibility that the flight might have to divert, his employer became irate…he was told to tell the operator that the airplane was not going to be redirected…he had flown into Aspen at night and was going to do it again (NTSB, 2002, p. 28)

4.3.6 REGULATORY BODIES

Accidents are also challenging for regulatory bodies. In the wake of a suspected suicide-related crash in the Pyrenees in 2015 the regulatory authority had to rapidly institute new rules requiring at least two occupants on the flight deck at all times. Another issue attracting scrutiny at present is the arrangements commuting pilots make to avoid fatigue; until recently this issue has been left to their individual professionalism but in the wake of the Buffalo accident the NTSB has been pressing the FAA to implement fatigue mitigation processes that have so far not been implemented. Regulators such as the USA’s FAA can be held accountable in the wake of an accident as was the case when a Delta Airlines Boeing 727 crashed at Dallas in 1988:

“...the FAA was aware of certain deficiencies in Delta's check airman program as far back as 1985. Additionally, in 1987, the incidents involving Delta flight crews and the findings of the 1987 inspection team should have indicated to Delta and the FAA that immediate corrective action was necessary...” (NTSB, 1989, p. 79)

In the UK the CAA has also attracted criticism in the past in the wake of two serious occurrences involving the now defunct Emerald Airways: The AAIB said that the CAA’s oversight programme had already identified deficiencies in the crew resource management aspects of Emerald’s operations, but it concluded:

*“The programme was ineffective in producing sufficient timely improvement. If it had been successful these incidents could have been prevented.” (*Flight Global, 2000)
This indicates that not even regulators are immune from fallout when safety is compromised.

4.4 FEASIBLE TRANSFORMATIONS

By understanding the human limitations outlined in this study it is feasible that the following transformations could be made:

4.4.1 TRAINING

Threat and error management (TEM) procedures could be devised on the basis of the new knowledge in this study. For instance, currently FCMs are never required to demonstrate their ability to transition from egocentric to allocentric navigation displays at short notice; furthermore they currently receive no simulated training in using an EFB in limited visibility. In the UK, FCMs only need to demonstrate low visibility taxiing at triennial intervals. To put this in perspective, they practice engine failures on takeoff during every proficiency check despite the fact that runway related incidents and accidents in poor visibility far exceed engine failures on takeoff. Because flying with degraded navigational information is more cognitively challenging than using a moving map display it is likely to reveal handling and management deficiencies in FCMs that would not be evident with access to normal instrumentation. In response to the Buffalo accident identifying low performing pilots and devising strategies for their training has been identified as a safety priority by the NTSB. This study identifies some explanations for degraded pilot performance that, as far as is known, have not previously been documented. The verbal strand of this thesis outlines how ineffective communication can induce error. This study highlights that support staff such as dispatchers, air traffic controllers and managers have all been an influence in accidents in the past, which suggests that they would also benefit from an understanding of how the way they communicate can affect flight safety. The concept of contextual cueing is not widely documented in the aviation literature despite clear evidence of its influence in reports spanning decades.

4.4.2 OPERATIONS

Accidents at Jakarta and Islamabad both involved pilots who probably underestimated the influence of spatial tasks upon working memory capacity. Working memory demand has been empirically and theoretically implicated in the production of errors by many researchers (e.g., Hitch, 1978, Anderson & Jeffries, 1985, Lebiere, Anderson, & Reder, 1994), although these studies have not examined systematic errors such as forgetting to extend the flaps because an interruption occurs at a critical moment. However, Byrne & Bovair (1997) have provided experimental evidence of the influence of working memory load on this type of post-completion error. The connection between very high cognitive load and error rate increase has also been demonstrated by Ayres (20001) and others. However, the exact nature of the relationship between problem complexity and increased error rates is unclear from the research. Sweller (2006) has emphasised the role of worked examples as a cognitive load reduction technique during skill acquisition and the reports indicate that flight crews can experience extreme cognitive load when they deviate from clearly defined problem solving routines. This was evident in a serious LOC incident at Newcastle in 2013 (UK AAIB, 2013) where the flight crew did not adopt a recommended procedure during a missed approach and subsequently made multiple serious errors. Whereas Sweller focused upon the process of problem solving, Ayres (2001) varied the intrinsic complexity of problems and observed the effect on cognitive load. Ayres found that as more brackets were added to an algebraic equation the error rate increased. He concluded that failures in working memory rather than poorly learned rules accounted for the variation and that the varying cognitive load experienced by problem solvers on these tasks was the likely cause of the observed pattern of errors. These two perspectives suggest that not only the complexity of the task but the manner in which it is communicated is likely to influence the cognitive load invoked. This means that when a controller issues a missed approach instruction in an unfamiliar way (as was the case in an accident at Sochi outlined in section 7.25) cognitive load may be increased simply because the task was not learned in the sequential steps now being used. On the other hand it may be that just “too many brackets” were present in the equation the flight crew were being asked to solve (as was probably the case at Newcastle). The notion that controllers might benefit from an increased awareness of their influence on flight crew cognitive load is supported by data from the NASA ASRS database and safety occurrences such as the one at Tenerife in the 1970s (UK AIB, 1981), Providence in 1999 (NTSB, 1999) and more recently at Newcastle (UK AAIB, 2013), all of which involved complex tasks which were made more difficult by the way in which an instruction was passed by a controller. This study also identified that those who support flight crews, including air traffic controllers, dispatchers and cabin crew are sometimes inhibited in their communications for a wide range of reasons. This study's taxonomy of unclear speech acts and their explanations represents a starting point for transforming communications between all those involved in aviation safety.

4.4.3 DESIGN AND PROCEDURES

Designers can also benefit from this research because there has been evidence of design deficiencies in some of the best aircraft in service. For instance in the 1970s the flap lever of the state-of-the-art Trident was modified in response to an accident and more recently the Boeing 777 autopilot engagement criteria were modified after nine related human-errors incidents had occurred. This study indicates that in a world free from other constraints it would be preferable for EFB displays to adopt the same orientation as the ND; however, even the modern Boeing 787 EFB owes its positioning and orientation more to the ergonomic requirements of the flight deck than to the human limitations outlined in this research. Transformations aimed at making procedures safer are also conceivable on the basis of this study. There is evidence that performing distracting tasks whilst taxiing, such as receiving load information and making cabin announcements has contributed to serious incidents at Hong Kong (Civil Aviation Department Hong Kong , 2011, p 26), Seattle (NTSB, 2008) and elsewhere. The effect of concurrent tasks upon cognitive load is well-documented and has been shown to adversely affect individuals' ability to retain orientation during locomotion (Lindberg & Garling, 1981). Research by Meilinger et al. (2008) measured the influence of secondary visual, spatial and verbal tasks performed whilst wayfinding and found that although the visual task interfered with wayfinding performance, it was concurrent spatial and verbal tasks that caused greatest interference whilst wayfinding. This is an important consideration given the loss of orientation experienced by the Lexington flight crew who had been performing a concurrent verbal task in the form of a conversation and visual tasks both inside and outside the cockpit whilst taxing towards the runway. It is the unauthorised aspect of the verbal interference that attracted most criticism in the Lexington accident report (NTSB, 2007a) but the human cognitive system cannot differentiate between an unauthorised conversation and a conversation that is encouraged by the operator such as a passenger announcement or a call to the cabin crew to sit down (one of the several concurrent tasks evident in the Hong Kong incident cited above) so it is evident that this human limitation is to some extent underestimated. There are numerous possible reasons why such procedures are widespread but not all of them are enacted to enhance safety. Perhaps the commercial requirements require a weighing of risk versus safety; alternatively it may be that those who implement such decisions simply lack sufficient insight of the flight deck environment to understand the distraction caused and its potential effect. Either explanation represents an impediment to change but by highlighting and documenting such risks it becomes more difficult to deny their existence. There are however, some designs and procedures that are likely to prove very resistant to transformation, such as the complete redesign of a flight deck to accommodate an egocentrically oriented EFB or the prohibition of distracting activities like answering ACARS messages whilst taxiing. By highlighting the risks associated even with procedures and designs that are unlikely to be transformed, FCM s will be better able to manage those risks themselves and remain safe. In a similar vein, some FCM activities such as violations of the sterile cockpit rule seem particularly resistant to transformation. Operators should be aware that by requiring their FCMs to perform the distracting activities described above, they probably weaken the force of their pronouncements prohibiting activities such as NPCs, which could encourage noncompliance. This study highlights some of the interactions that might lead to NPCs, and cautiously suggests that an understanding of the reasons for this particular type of violation is more likely to result in the required transformation than simply reiterating the rule every time an accident is investigated.

4.4.4 AWARENESS AND EMPATHY

The examples cited earlier of a dispatcher at Birmingham, Alabama (NTSB, 2014b), an air traffic controller at St Kitts (UK AAIB, 2010a) and even a passenger (NTSB, 2002, p. 28) who were unaware of their influence upon the actions of a flight crew hints at a disturbing lack of awareness and empathy afflicting aviation safety. The occurrence literature suggests that even those on the frontline of aviation safety such as air traffic controllers and pilots underestimate the importance of understanding one another's role. For instance, it is clear from the literature that some air traffic controllers are unaware that if they issue a takeoff clearance whilst an aircraft still has a runway or taxiway to cross before reaching the active runway there is an increased risk of a wrong runway takeoff. None of the twenty pilots spoken to during the development of this research knew about this human-limitation or were aware that it was a well-documented threat. This exact contextual condition has resulted in several very serious incidents in which the controller did not notice a takeoff commence at the wrong location. Whilst the first instance could be considered a "normal accident" (Perrow, 1984), almost identical instances that followed suggest a systemic failure. A stated aim of the SFP construct was to act as a repository for knowledge relating to repetitive contexts that have been shown to be linked to substandard flight crew performance. Access to such a store of knowledge could mitigate the risk of situations like the one at St Kitts (UK AAIB, 2010a) where the controller appeared to be unaware of the potential for a flight crew to make the error of lining up for takeoff half way down the runway, and a flight crew who probably expected him to warn them if they were making such a mistake. As far as is known, there is no existing repository containing the accumulated knowledge relating to this category of occurrence and other recurrent categories such miscommunication or loss of positional awareness. The potential transformations to operational procedures outlined in this chapter all require that everyone involved in flight safety understands what the other's problems are. This ability to perceive and react to another's emotional state has been conceptualised in organisational research (Salovey and Mayer, 1990) as emotional intelligence (EI) and is now being recognised as an emerging core skill for flight crews; however, there is no clear evidence that it is being embraced by others in the aviation safety system. Although this thesis unavoidably contains content of a technical nature, most of the general principles outlined are likely to be comprehensible to a wide readership within the aviation safety system, not just those on the frontline of aviation safety.

4.4.5 SUMMARY OF CHAPTER 4

Chapter four has outlined the conceptual model used as a framework for this research. It has presented the characteristics of the aviation accidents that are occurring at present and identified a mismatch between the systems approach to aviation safety and what happens in the real world. Aviation safety's stakeholders have been identified and a brief sketch of their responsibilities, motivations and roles has been proposed. Finally, the feasible transformations that could flow from this research have been outlined.

PART II: EXPERIMENTAL APPROACH AND RESEARCH METHODS

OUTLINE OF PART II

Chapter five begins by highlighting that although flight deck conversations have been identified as a threat to aviation safety, as far as is known no previous research of the type described in this thesis has been undertaken. A description of how the talk heard in other institutional contexts has been the subject of meaningful research introduces the idea that similar processes might be effective in understanding the underpinnings of flight deck conversation. The chapter then outlines how unclear communication has contributed to a range of accidents in aviation and several other safety critical disciplines and how linguistic data from more general research populations can provide insights into the role of miscommunication in SFP. The research scope then widens out to consider the effect of context upon flight crew performance. As far as is known, this strand is original with no previous relevant research to replicate. The three contextual cueing hypotheses outlined in this thesis were derived from the qualitative data in the occurrence literature. Chapter five concludes with an explanation of the specific types of spatial awareness challenges that have formed part of the situational context in advance of an accident. The chapter then proposes a link between these challenges, cognitive load and reduced human performance.

CHAPTER 5

BASIS FOR A MIXED METHODS APPROACH TO THE STUDY OF SFP

This chapter outlines the rationale behind the various different experimental methods used in this study. Section 5.1 and its subsections address the verbal strand. Section 5.2 and its subsections address the contextual–cueing strand. Section 5.3 and its subsections address the spatial-awareness strand.

5.1. BASIS FOR AN EXPERIMENTAL APPROACH TO THE VERBAL STRAND

5.1.1 OVERVIEW OF THE VERBAL STRAND

This section outlines the basis for the experimental approach to the verbal strand of this thesis. Section 5.1.2 outlines the role of concurrent tasks and distraction. Section 5.1.3 introduces the concept of discourse analysis (DA) and explains how it has been used to research other similar contexts. Section 5.1.4 outlines how the literature related to institutional talk provided a framework for the study of a phenomenon which, as far as is known, had not been subjected to any previous research in the aviation context. Section 5.1.4 introduces the unclear communication research which also formed part of the verbal strand. Section 5.1.5 outlines how discourse analysis has featured in historic accident reports thereby providing a rationale for its use in this study of unclear communications. This research could locate no comparable research into the specialised talk that is heard on the flight deck so it was necessary to identify and research similar unrelated contexts. The chapter ends with a methodological note related to the role of the lone researcher in this type of qualitative research.

5.1 2 CONCURRENT TASKS AND DISTRACTION

Previous chapters have highlighted the role of non-pertinent conversation in SFP related accidents. In addition to an empirical relationship with accidents such as those at Lexington and Buffalo there is previously cited evidence from concurrent task research that NPCs are likely to be a source of distraction to flight crews. In addition, research using fMRI indicates that the response of the auditory cortex to task irrelevant sounds may result in its deactivation during demanding auditory tasks with conflicting processing requirements (Rinne et al., 2009), which means that by conducting non-pertinent conversations flight crews expose themselves to an increased risk of omitting an important task. The distraction caused by a concurrent task such as conducting a conversation whilst taxiing the aircraft represents a particularly potent threat to safety because its precise effect varies depending on the degree of overlap between the types of information requiring processing. Research by Kim & Osterhout (2005) suggest whilst a pilot above may be able to conduct conversations both within the flight deck and to a controller without apparent distraction there may be considerable disruption of semantic processing, with the consequential risk of losing situational awareness. Kim & Osterhout’s research indicates that dual concurrent tasks affect information processing in a complex fashion related to how closely the sources of distraction are related semantically. The complexity of this concept suggests that individuals FCMs who do not possess a detailed understanding of cognitive limitations may not identify this as a threat. This potential lack of awareness may underpin the observed willingness of flight crews to contribute to their own distraction. The aim of the non-pertinent conversation section of the verbal strand research was to identify some of the most recurrent types of conversation that occur on the flight deck and to propose explanations for their occurrence.

5.1.3 DISCOURSE ANALYSIS

A detailed literature review indicated that much of the existing research into verbal behaviour on the flight deck tended to focus on the structure of language rather than the meanings of what was said. This has resulted in several conversation-analysis (CA) studies but very few formal studies of the discursive features of what is heard. Nevile & Walker's (2005) influential paper "a context for error" is an example of how the structural features of flight deck conversation can yield insights into the mood in the cockpit or the working relationship of the pilots, whereas one of the aims of this research was to identify the underlying reasons that flight deck conversations occur, with a view to mitigating their effect. As far as is known, this is the first research to ask pilots their opinions on a range of recurrent conversation types and to propose motives for their occurrence. Discourse analysis (DA) is the study of talk and texts; it is a set of methods and theories for investigating language in use and language in social contexts (Wetherell et al., 2001); this simplified definition, whilst adequate for much of the conversation evident in the transcripts, downplays the complexity of some of the institutional talk heard in the transcripts examined in this research. Whilst Nevile & Walker's (Ibid.) paper concentrated on the structural features of the talk that preceded an accident, investigators' reports frequently go beyond this structural approach by assigning meanings to what has been said. In such cases the investigators are engaged in an informal kind of DA which almost always focuses upon the meanings that apply in the institutional context in which the speech took place. This is an example of critical discourse analysis (CDA) and much of the current research was based upon the ideas of CDA. Throughout this thesis the idea that the flight deck represents a unique context will be evident. In terms of discourse, this notion is evident in two separate reports where pilots use informal language (the terms *at your leisure* (NTSB, 2007a. p. 72 and *just for a giggle* ATSB, 1995, p. 24) that attract negative evaluations from investigators suggestive of a casual attitude, which would hardly apply in a less formal setting. Tuen Van Dijk (2001) described how groups who share specialized knowledge, such as academic, scholarly, scientific, technical and other kinds of ‘expert’ knowledge tend to occupy what he calls “common ground”; that is they share a common sense belief generally accepted to be true by all competent members. The current research supports Van Dijk’s (2001) notion that in addition to specialist discourse centred upon technical terminology there is less formal discourse within such communities that can reveal the argumentation patterns, the dominant schemas, the preferred topics, the rhetorical and metaphorical devices that prevail within that specialised community. It is this informal flight deck discourse that is examined in the verbal strand of the current study. Because the discourse heard from pilots who have been involved in a safety occurrence is often the subject of critical analysis it is also important to consider how discourse *about* a particular group can be influenced by the meanings individuals attach to those groups; for instance one might have differing conceptions of the meaning of professional behaviour when applied to a footballer than when applied to an airline pilot. Although CDA’s undeniable focus upon power and dominance was not an intended direction for this research, by a process of induction it emerged that a significant amount of the talk evident in the transcripts could be explained in those terms. As far as is known, no previous research has examined flight deck conversation from the CDA perspective and it should be emphasised that although this study was based upon the CDA related literature it was not formal CDA research. However, in light of the NPC research outlined in this thesis it will be clear that any discussion that omitted these factors would be incomplete. Whilst the work of Van Dijk and his peers facilitated the analysis of many of the speech acts in the transcripts there were others that it was impossible to attribute to the exercise of power or dominance so it was necessary to look elsewhere. Because the flight deck was considered an institutional setting, a review of existing research into other such settings was undertaken. Descriptions of discourse analysis studies involving analysis of doctor/patient talk (Wodak, 2006), legal testament (Shuy, 1993), legal discourse (Wagner and Cheng, 2011), and a range of other specialised contexts demonstrates its wide acceptance for purposes as diverse as medical policy changes, legal defence and training. The range of methods that qualify as discourse analysis in the literature is quite wide, with examples of tape recorded extracts that sometimes appear to have been chosen primarily to support a given argument or in other cases just an extract from a book with almost no context except for the text within which it was embedded. The current research sought a more rigorous set of criteria for consideration of talk as an indicator of the philosophies and ideas that Van Dijk referred to. In order to be considered, a fragment of text would have to be transparently similar to those it would be categorised alongside; this was particularly important as this research was conducted by a lone researcher. Each fragment within a category would need to have been clearly evident in at least two accident report CVR transcripts.

5.1.4 INSTITUTIONAL TALK

Because the concept of an NPC was unknown outside aviation it was necessary to seek out more generalised research and adapt it to the aviation context with the help of aviation SMEs. A review led to the work of Jones and Pittman (1982) and an interpretation and review-based taxonomy by Bolino and Turnley (1999) which outlined and explained forty four types of verbal behaviour that had featured in institutional settings. The current study adapted Jones and Pittman's research methodology which was based upon a six step procedure proposed by Hinkin (1998) for the development of measures. The procedure used in this study was a simplified version of Hinkin's procedure involving fewer steps: item generation, questionnaire administration, initial item reduction and replication. The absence of steps involving statistical tests was appropriate due to the low number of participants and the availability of alternative means of establishing content validity. The resultant taxonomy was substantially similar to Bolino and Turnley's.

5.1.5 UNCLEAR COMMUNICATIONS

Despite rarely being cited as a factor in accidents that exhibit substandard flight crew performance, unclear communications are frequently in the background in such accidents. For instance, in 1997, the investigation into a CFIT accident at Guam (NTSB, 2000) found that inappropriate communications had been a contributory factor. The major causes of this accident were the captain's failure to adequately brief and the first officer's and flight engineer's failure to cross check the captain's execution of the approach. Similar patterns of failed communication have been documented in nuclear power plant personnel (Hirotsu, 2001) and railway maintenance workers (Murphy, 2001). The practice of developing taxonomies of inappropriate communications is a well-established research method with examples from the nuclear industry (Berman and Gibson, 1994) and the railway maintenance industry (Gibson et al., 2006) and others. Much of the existing research into failed communication involving pilots relates to their verbal interactions with air traffic controllers. Whilst this is an important factor addressed in the current research, another major focus of this research was upon instances where intra-cockpit communication failed to prevent an accident. As far as is known, no existing taxonomy of unclear communication between flight crew members exists. This research employed a process known as thematic-analysis, whereby codes were assigned to words or phrases in order to produce categories of speech acts (Boyatzis, 1998). Some of the categories were complex, requiring detailed explanation whereas others were simple and readily understood. Boyatzis explains that codes of varying complexity can be utilised in thematic analysis whilst still retaining the same rigour. Some of the codes in this research were theory driven and others are derived from a bottom-up analysis of what was heard and the outcome that resulted. Qualitative-analysis is amenable to such a combination of approaches. Bottom-up analysis inevitably invokes some of the researcher's subjective opinions regarding what is and isn't unclear. This type of subjectivity is evident both in research papers and in investigation reports, where investigators frequently draw inferences that far exceed the literal meaning of what has been said. Thus a precedent exists whereby a third party researcher can offer interpretations of what has been said and invite scrutiny of those interpretations. In many cases an interpretation is the only possible means of examining what was said because the speaker is not available to explain. To mitigate the effect of lone researcher subjectivity all of the examples of unclear communications included in the taxonomy of unclear communications that forms part of this thesis have been clearly identifiable in advance of more than one aviation accident or incident. Furthermore, each of the communication types in the taxonomy is explained with reference to peer-reviewed research. Finally, the potential benefits of proposing even a subjective taxonomy of unclear communication types compare favourably with simply addressing unclear communications in the ad hoc fashion that is evident in some reports.

In summary, a form of discourse-analysis is evident in accident reports, indicating that subjective accounts provided by individuals who have not received formal training in linguistics are considered suitable for inclusion in influential literature. As far as is known, no previous research had attempted to organise some of the most recurrent instances of unclear language into categories so that they can be explained. Thematic-analysis was considered an appropriate and effective means of categorisation. Multiple sources were accessed in order to develop the taxonomy of unclear communication outlined in this thesis.

5.2 THE BASIS FOR AN EXPERIMENTAL APPROACH TO THE CONTEXTUAL CUEING STRAND

5.2.1 OVERVIEW

This chapter outlines the basis for the experimental approach to the contextual cueing strand of this thesis. Section 5.2.2 provides examples of recurrent instances where flight crews appear to have been influenced by aspects of the prevailing context to make an error or omission. Section 5.2.3 introduces the concept of contextual cueing and describes how related research has mainly concentrated upon its influence on visual processing. This is followed by an explanation of the rationale for adapting the contextual cueing paradigm (See Chun et al., 2000 for a review) theory to a range of other perceptual modalities more fitting to the aviation context. Section 5.2.4 details the methods researchers have used to explore contextual cueing in existing research and explains how these needed to be modified for the experiments conducted in this research. Because this study elaborated upon existing research, the methods did not replicate existing research but were adapted to the individual phenomenon being examined. For instance, in some of the experiments response time (RT) was considered a useful measure of cognitive processing whereas in others the accuracy or appropriateness of response to a stimulus was more relevant than RT.

5.2.2 THE EVIDENCE FOR CONTEXTUAL CUEING AS A FACTOR INFLUENCING SFP

Contextual cueing occurs when aspects of the prevailing context encourage a flight crew to behave in a way that has been appropriate when that context applied on previous occasions. This phenomenon can have a wide range of effects relevant to SFP. A seminal runway accident in Tenerife involved a captain whose training role meant that he spent much of his working life in a simulator, where he performed the role of instructor but crucially, issued clearances that are normally issued by an air traffic controller. It was hypothesised in the Spanish report (Ministerio de Transportes y Communicaciones Subsecretaria de Aviacion Civil, 1978, p. 109) that the foggy conditions, coupled with his experience as a simulator training pilot may have provided sufficient contextual cues to result in his incorrect belief that he had been cleared to takeoff. Ethnographic observations conducted for this study found that less attention was paid to takeoff and landing clearances during simulator sessions than in real life operations so the foregoing explanation is plausible. The literature indicates that flight crews become accustomed to receiving certain communications at certain times. This phenomenon is illustrated by the numerous documented instances of flight crews who incorrectly take off on the next runway like surface they encounter after they receive their take off clearance. This has resulted in numerous taxiway takeoffs and wrong runway use occurrences. The Norwegian accident investigation agency reports that one airport in Norway has experienced several serious incidents in the vicinity of a single runway holding point, including three attempted taxiway takeoffs (AIBN, 2010, p. 22). In two of these instances the flight crew had received their takeoff clearance when they were some distance from the runway. This unexpected contextual influence is sufficiently well documented that some airports, such as Auckland in New Zealand, avoid passing a takeoff clearance until the aircraft is in the correct position (AIBN, 2006, p. 8). There is also considerable evidence in the occurrence literature to suggest that contextual cueing has also played a part in omissions related to both landing gear and flap selection. The reports into several flapless takeoff accidents (e.g. NTSB, 1988 and CIAIC, 2008) suggest that particular phases of flight tend to be associated with certain tasks having been completed. For instance, once the aircraft is lined up on the runway for takeoff it is very unusual for the flaps not to be in the extended position, so in this flight phase there may be a tendency to be less diligent in checking them because the likelihood of them not being extended is so low. It will also be demonstrated how an existing technical aircraft defect has provided the context for a flight crew to misattribute a subsequent defect in a way that would be unlikely in the absence of the pre-existing defect. The next section describes how existing contextual cueing research was adapted to explain some instances of the SFP related phenomena just described.

5.2.3 CONTEXTUAL CUEING, PERCEPTION AND THE PILOT

Visual objects are contextually related if they tend to co-occur in our environment, and a scene is contextually coherent if it contains items that tend to appear together in similar configurations (Bar, 2004). The contextual cueing research paradigms upon which this study is based typically involve the repetition of visual scenes with changing characteristics but which retain some invariant features. After repeated exposure, the position and configuration of features of the visual scene become associated with both local and global contextual information. The example above of the simulator instructor at Tenerife is one of many imaginable contextual situations where global context could influence a flight crew to believe a condition has been met when it has in fact been omitted. Although, as far as is known, this is the first research to operationalise the contextual-cueing paradigm in the aviation context, the phenomenon is recognisable in the occurrence literature. There are instances of flight crews entering runways without clearance, taking off from taxiways, omitting to extend the landing gear and incorrectly configuring the aircraft for takeoff, among other instances of SFP that hint at the influence of global context. Although the traditional understanding of global context refers to what individuals observe in their spatial environment, this study broadened the concept to include aspects such as one’s position in space, the status of systems and the meanings attached to certain alerts. The premise of this study was that via a process known as implicit learning FCMs come to associate aspects of their global context with aspects of their local context such as the relationship between entering the runway for takeoff and having the flaps in a takeoff position. Global contexts are also implicated in misattribution errors related to the weather as in a takeoff accident at Washington (NTSB, 1982), a pre-existing defect at Palmerston North (TAIC, 1995) and system status at Jakarta (KNKT, 2012). It should be emphasised that none of the associated accident reports cited contextual cueing as a factor but it is evident that had these factors not been present the accidents might have been avoided. Explicit acknowledgement of the existence of contextual cueing as a relevant phenomenon was found in analysis of a CFIT accident at Cali by the Flight Safety Foundation (1998, p. 13), where it was hypothesised that the captain may have incorrectly misattributed the confusing indications he was seeing on his navigation instruments to reports of sabotage of radio equipment that he had been aware of. Had this context not existed it is likely that he might have been more critical of his own actions rather than pursuing his false hypothesis. In addition to misattribution, context also plays a part in misidentification; our experience of the visual world dictates our predictions about what other objects to expect in a scene and their spatial configuration. Evidence for the role of context in object memory comes primarily from research on object perception or object identification in humans, which has demonstrated the role of contextual information in enhancing object identification (Palmer, 1975; Biederman et al., 1982; Boyce and Pollatsek, 1992; Davenport and Potter, 2004, cited in Hayes et al., 2007). Although in everyday life it may confer a cognitive advantage to be able to predict the status of an aspect of one's activity on the basis of what usually occurs in that context, in aviation the pursuit of cognitive economy is less important than accuracy. Flight crews are taught from an early stage to check and double check the status of critical systems such as the flaps but the literature indicates that when flap extension before takeoff is omitted it usually occurs in familiar contextual conditions. A detailed review of this type of error found that it is often attributed to post completion error or a failure of prospective memory. Whilst these phenomena provide explanations for the original omission they provide little insight into why the omission was not noticed despite, in many cases, a checklist being completed. Evidence from the investigation into the previously cited accident at Cali (ACRC, 1996) confirms that flight crews sometimes make assumptions (in the Cali case, relating to how waypoints were sequenced by the flight management computer) based upon *a priori* knowledge, but Bar (2004) suggests that even this may not represent the full potential for error, noting that such context driven predictions can allow individuals to choose not to attend to an object at all if none of the possible identities suggested by the context are of immediate interest. This means that if a pilot cannot conceive of a circumstance in which the flaps would not be extended when the aircraft is lined up for takeoff then the configuration is unlikely to attract his/her attention. There is also thought to be a difference between contextual relations and semantic relations that may be important in this context. Possessing a priori knowledge that the flaps are extended is likely to be driven by the knowledge that all takeoffs require some degree of flap extension, whereas knowing the exact configuration requires a deeper semantic understanding of the particular configuration. This proposal introduces the likelihood that different regions of the brain might be involved in quite similar contextual settings which raises the question how might this complex system be organised and activated? A recurrent model involves the construction of mental scripts (known in psychology as schemas) that contain all the expectations formed from previous experiences. The potential problem with the application of schemas is that on occasions the wrong schema will be activated or one may have no previous experience upon which to base one. It is also important to acknowledge research by Gottesman & Intraub (1999) which suggests that sometimes people extrapolate beyond the boundaries of their schema in a phenomenon known as boundary extension. Similarly, in false memory experiments participants have reported seeing something that was not present in the picture they viewed but was contextually related to a scene that did contain the object. These two limitations of schema-based processing would seem to be a potential factor in the small but significant number of instances of flight crews who mistake a taxiway for a runway despite multiple visual cues that distinguish one from the other (e.g. ASC, 2002: AIBN, 2006: AIBN, 2010). There are also documented cases of pilots who report with some certainty that they have observed the position of, for instance, the flaps despite retrospective evidence to the contrary (NTSB 1989, p. 62).

5.2.4 PREVIOUS RESEARCH METHODS AND THE CURRENT RESEARCH

From the foregoing section it can be seen that recalling a previously completed or omitted action is particularly relevant to the aviation context. Reinstatement effects are commonly researched and typically find evidence of better memory when the learning environment is reinstated at test than when testing occurs in a different environment. Whilst such experiments usually seek to make the environments used as perceptually distinct from each other as is possible, the requirement in this research was to make them as realistic as possible even if the changes were subtle. Whilst more general research has performed manipulations such as moving items in a room setting, the current research made very specific manipulations such as introducing an alert that was either congruent or incongruent with the contextual situation. Other researchers have manipulated the geographic location in which learning took place; Godden and Baddeley (1975) manipulated context by having scuba divers learn and recall word lists on land or underwater, whilst Smith and Sinha (1987) used a flotation tank versus a lounge. The current study contended that the accuracy of FCMs' recall of their aircraft's configuration may be similarly affected by a mismatch between contextual conditions that usually prevail during learning and those they experience at recall. Although Smith and Vela (2001) present considerable evidence challenging the influence of incidental environment changes it should be pointed out that in the experiments outlined in this research the manipulations represented realistically plausible options albeit less likely ones than the norm. So despite the documented limitations of manipulating contextual environments and observing the effects it was considered an effective research method. As far as is known there is no existing research directly comparable to the current study in which the participants' prior knowledge of system status is a dependent variable defining the context. There is however, experimental fMRI evidence (Summerfield et al., 2006) that information stored in long term memory can drive the orienting of spatial attention, indicating that prior knowledge represents a component of context. Experimental research by Beesley et al. (2015) is among many studies to demonstrate an advantage in visual search when an individual has had previous exposure to the stimulus. The current study is novel in two respects; firstly it is not concerned with RT but accuracy; secondly, this study hypothesised that contextual effects found to be advantageous in most studies may be implicated in the commission of errors in the aviation context where the accuracy of behaviour is more important than the speed with which it occurs. One area where the current study converges with existing studies is in the area of experimental control. Although the current research required an ethnographic approach involving real life scenarios it was possible to maintain a high degree of experimental control by using a simulator. Ethnographic observation has been effectively applied to research into intravenous medication human errors (Taxis & Barber, 2003), the lifestyle of night freight pilots (Bennett, 2010) and a range of high reliability organisational settings (Bourrier, 2011). In summary, this study elaborated upon the ideas contained in the contextual cueing literature but deviated considerably from the subject matter of much of the existing research. An extensive review of the aviation literature found very few explicit references to contextual cueing in relation to a serious incident; this was useful at two levels insofar as it established that the concept was not completely unknown in the aviation context and also that it was probably under researched. The aim of the current research was to operationalise contextual cueing and to test three hypotheses based upon realistic instances from the occurrence literature.

5.3 THE BASIS FOR AN EXPERIMENTAL APPROACH TO THE SPATIAL AWARENESS STRAND

5.3.1 OVERVIEW

This section outlines examples of accidents and incidents where there exists clear evidence that the flight crew were unaware of their heading, their position or both. Section 5.3.2 identifies and describes recent relevant accidents. Section 5.3.3 describes the contextual conditions that have applied in these accidents and introduces the type of phenomena that will be examined in detail later in the thesis. Section 5.3.4 outlines research from more general populations that provided direction to the research outlined in this thesis.

5.3.2 THE EVIDENCE IN SUPPORT OF LOSS OF SPATIAL AWARENESS AS A FACTOR INFLUENCING SFP

A Sukhoi Superjet flight crew at Jakarta (KNKT, 2012) lost awareness of their aircraft's current heading and the heading they needed to fly to navigate safely to their intended destination. An Airbus flight crew at Islamabad (PCAA, 2010) lost control of their aircraft during confusion relating to both their heading and position. A Boeing 757 flight crew at Cali crashed into terrain after deviating from their planned route after their electronic map became confusing. These are just three examples of accidents involving fully serviceable aircraft flown by experienced flight crews with access to a computer generated ND with capability to display an egocentrically oriented representation of their spatial environment. Each of these accidents meets at least one of the criteria to be considered an instance of SFP.

5.3.3 SPATIAL AWARENESS, COGNITIVE LOAD AND THE PILOT

The magnitude of the errors involved in each of the instances above suggests that the FCMs had little or no idea where they were headed. In each of the accidents cited above, the flight crew were deviating from their planned route. This study highlights the cognitive differences between navigating along a pre-planned route and navigating off the planned route. An important aim of this research concerned how airline pilots' cognitive load is affected during reorientation tasks. If the process of mentally orienting can be shown to affect cognitive load, then what is the effect on decision making and flight crew performance?

5.3.4 PREVIOUS RESEARCH METHODS AND THE CURRENT RESEARCH

The most relevant existing research comes within the category of wayfinding (See Darken & Petersen, 2001 for a review). None of this research directly relates to aviation operations but clear parallels were apparent. Individual differences in spatial ability have been examined using pointing experiments (Gramann et al., 2006). Memory for spatial layouts has also been examined by asking participants to rehearse a route and subsequently draw a line to a known position they are unable to see (Witmer, et al., 1995). Pointing experiments by Frankenstein et al. (2012) indicate that even familiar spatial environments were more readily comprehended when a reference frame based upon north was adopted. Response time (RT) was used by Loftus (1978) as an indicator of the amount of effort required during comprehension of varying compass representations. There is also considerable research of the built environment that differentiates between environments that are readily understood and those with the potential to confuse. Research by Raubal & Egenhofer, (1998) used participant interviews during the development of a computational model of complexity in the built environment. Airports attract considerable scrutiny in terms of being confusing to passengers. The structural features of an airport were found by Seidel (1982) to have a strong influence upon people's wayfinding behaviour, as was previous experience with similar layouts. The frequency of any previous visits was also found to be a considerable help in wayfinding. No comparable research could be found into how pilots navigate around an airport's taxiways and runways, particularly if they have to perform large mental rotations. As with most navigation tasks previous experience increases familiarity and facilitates the task. Research by Shepard & Metzler (1971) has found that RT is an effective measure of how readily a particular configuration is recognised and this is the measure used in the current research. The experimental component of the current research was exclusively concerned with how RT varied during two tasks indicative of spatial ability. On the basis of the experimental results and interviews with participants, the general spatial awareness literature was considered from the perspective of a pilot.

CHAPTER 6

RESEARCH METHODS

The three research strands outlined in this thesis employed a range of ethnomethods including a questionnaire, thematic analysis of texts, experimental simulation, ethnographic observations, interviews and statistical analysis.

6.1 THE CONVERSATION RESEARCH

The conversation section of the verbal strand used questionnaires and unstructured interviews with pilots to generate findings that were analysed from a critical discourse analysis perspective. The questionnaire was based upon a taxonomy of impression management strategies that has been deployed in other institutional settings, modified for the aviation context. The data sources used during questionnaire development were four carefully selected CVR transcripts from the NTSB accident database that were considered by the researcher, on the basis of an extensive literature review, to be representative of the type of conversations heard in advance of an accident. The CVR transcript from a seminal accident at Buffalo was instrumental in determining the orientation of the conversation research towards impression management.

6.1.1 PARTICIPANTS

In addition to the airline pilots involved in the piloting of this study (n=13), thirty seven current airline pilots were recruited to complete an online survey relating to flight deck conversation. In order to obtain a representative sample of airline crews it was decided to avoid recruitment by social media, which would have been easier than the method used and would have probably resulted in a higher number of participants. By personally approaching suitable individuals on an opportunity basis it was possible to achieve a very high response rate and a very diverse demographic. Although this was a labour intensive and time consuming process it ensured that the participant pool was representative of rank, culture and gender. There were pilots from low cost, charter, freight and scheduled operators. Instructors, examiners, as well as line pilots contributed. There were pilots in their first year of airline operations and others with decades of experience. Participants were of various nationalities including German, British, Canadian, Australian and American. This cultural diversity was considered essential given the dominance of data from NTSB database CVR transcripts originating in the USA in the development of many of the conversation types under consideration in this research. The recruitment of suitable participants by personal approach took several months to complete. No payment was offered for participating. Collection of personal data on participants was kept to a minimum consistent with the objectives of the research.

6.1.2 MATERIALS

A questionnaire (See Appendix B) detailing twenty eight conversation types and seven explanation categories was developed for this research. Microsoft Excel and SPSS were used for analysis of quantitative data.

6.1.3 PROCEDURE

The participants completed the survey online after a briefing conducted either face to face with the researcher or via the instructions on the website. The instructions and description of the survey provided to participants is shown at Appendix B. The instructions included an internet address where any questions or difficulties could be discussed with the researcher; none of the participants found it necessary to use this facility. The participants were advised that they could discontinue the survey at any time they chose but there was no indication that anyone did so. The survey instructions encouraged participants to offer alternative explanations if they thought it appropriate. The quantitative data were analysed and ranked in frequency order.

6.2 THE UNCLEAR COMMUNICATION RESEARCH

6.2.1 PROCEDURE

The unclear communication research also made extensive use of the NTSB accident database, in this case to identify recurrent instances of failed communication. There were also important instances from the UK AAIB reports and from the TAIC in New Zealand as well as others. A corpus of nineteen aircraft accident report CVR transcripts was analysed for the presence of unclear communication exhibiting the characteristics associated with unclear communication in the linguistics literature. The nineteen transcripts were chosen from the larger corpus used for other sections of this research on the basis of their suitability for this study of unclear communications. Details of the transcripts used for this section appear in upper case in Appendix A. The requirements for inclusion were that the transcript should be from a reputable source such as an investigating authority and that there was no evidence of relevant sections being omitted. Electronic concordancing proved insufficiently sensitive to the fine detail of aviation related discourse to be useful so a manual concordancing was undertaken by the researcher. Figure 6.1 is a segment of a CVR transcript highlighting multiple instances of the phrases “autopilot” and references to the heading. By colour coding different phrases it was possible to identify recurrent verbal themes that preceded an accident.

02:43:55 CA: Autopilot
02:43:58 CA: Not yet
02:44:00 FO Autopilot in command sir
02:44:01 CA: Exclamation remark
02:44:02 : Sound of A/P disengage warning
02:44:05 CA: Heading select
02:44: 02:44:07 FO: Heading select
02:44:18 CA: See what the aircraft did!
02:44:27 FO: Turning right sir
02:44:30 CA: What?
02:44:31 FO: Aircraft is turning right
02:44:32 CA: AH
02:44:35 CA: Turning right?
02:44:37 CA: How turning right
02:44:41 CA: OK come out *(referring to autopilot or "come out of the turn?)*
02:44:41 FO: Over bank
02:44:41 CA: Autopilot
02:44:43 CA: Autopilot
02:44:44 FO: Autopilot in command
02:44:46 CA: Autopilot
02:44:48 FO Over bank, over bank, over bank
02:44:50 CA: OK
02:44:52 FO: Over bank
02:44:53 CA: OK, come out
02:44:56 FO: No autopilot commander
02:44:58 CA: Autopilot
02:44:58 EC1: Retard power, retard power, retard power
02:45:01 CA: Retard power
02:45:02 : Sound similar to overspeed clacker
02:45:04 CA: Come out
02:35:05 FO: No god except...
02:35:05 SV: "whoop" sound similar to ground proximity warning
02:45:06 END OF RECORDING

Figure 6.1: A section of a CVR transcript after manual concordancing.

As a lone researcher the potential for loss of objectivity was continuously monitored during the research by conducting unstructured interviews with current pilots. Database searches were not an effective means of identifying relevant accidents because unclear communication is rarely examined in detail in accident reports; for this reason a detailed examination of any potentially relevant accident reports was undertaken. This was facilitated by the researcher's detailed knowledge of the accident literature spanning several decades. Although this corpus is unlikely to include all the instances of unclear communication in aviation accidents, each of the instances outlined in the research represented a recurrent example from the literature and the explanations proposed were based upon peer-reviewed research. From the textual analysis conducted for this study a preliminary taxonomy of unclear communications was developed for each of three dominant categories of SFP-related occurrences. It is important to emphasise that this was a preliminary treatment of a complex subject that ideally would involve professional conversation analysts, psychologists and a range of other experts to develop its full potential.

6.3 THE SPATIAL AWARENESS RESEARCH

The spatial awareness research utilised the experimental method to examine the link between spatial tasks and cognitive load in order to understand the sudden onset of SFP in some documented safety occurrences.

6.3.1 EXPERIMENTAL METHOD (EXPERIMENT ONE)

6.3.2 PARTICIPANTS

Twenty current airline pilots all employed flying a variety of ND equipped aircraft were recruited on an opportunity basis. All the participants had in excess of 5000 hours of airline experience so could be considered uniformly experienced. No payment was involved.

6.3.3 APPARATUS

A Lenovo laptop computer loaded with SuperLab 5 © software was utilised to provide randomly presented stimuli and record RT with millisecond accuracy. Adobe Photoshop ™ software was utilised to prepare the stimuli. Modified approach charts of a type familiar to the participants were used.

6.3.4 STIMULI

Stimuli consisting of thirty six separate runway depictions on a realistic approach chart (See Figure 6.2) were loaded onto a Lenovo laptop computer. All the participants were familiar with the layout and format of the charts used. Excess detail was removed from each chart to avoid distraction from the orientation task. In particular, all written reference to runway orientation was removed from each chart. The rotation tool in Adobe Photoshop enabled the accurate rotation of the runway depictions in ten degree stages resulting in thirty six separate charts, each with a different orientation. The experiment was compiled using Superlab 5© software. The depictions were randomised and the software was configured to capture response time in milliseconds.

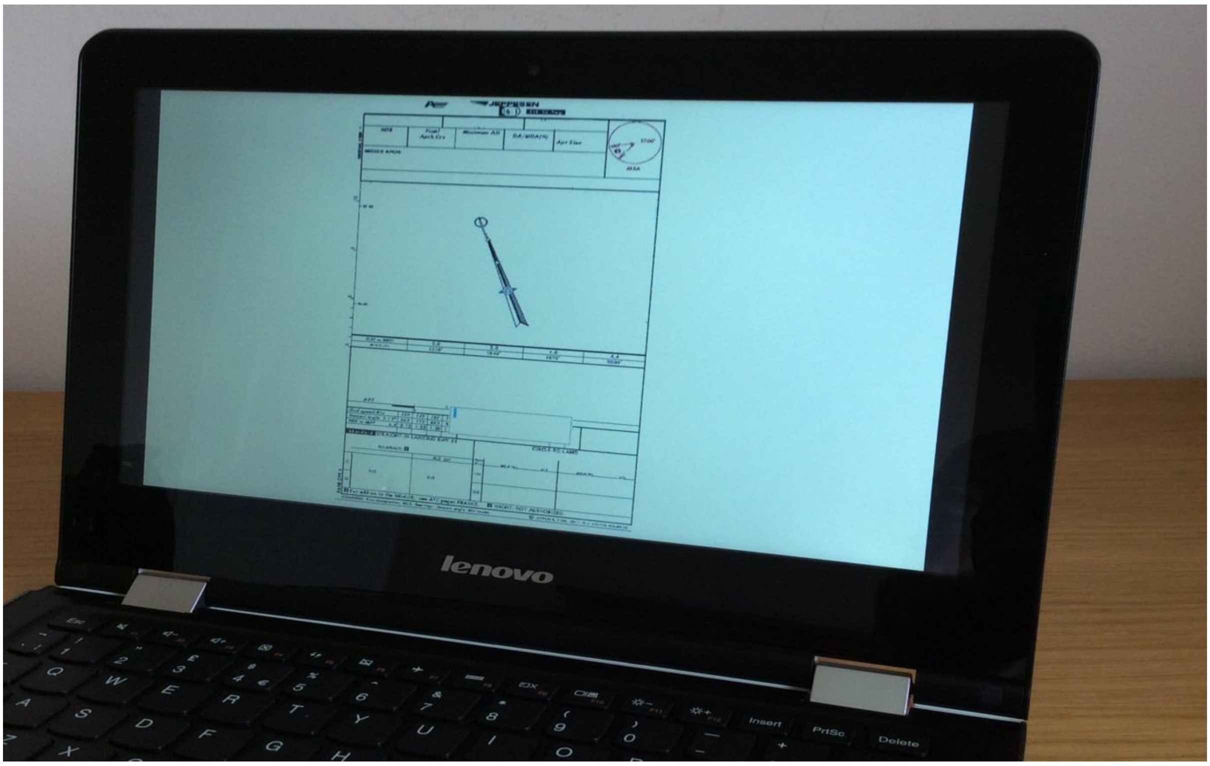


Figure 6.2: The laptop computer used in experiment one with the runway direction stimulus shown

6.3.5 DESIGN AND PROCEDURE

Each participant completed a single block consisting of thirty six trials. The complete process took less than ten minutes. Participants were briefed verbally before the experiment and this was followed by a screenshot on the laptop reiterating the verbal instructions, this was followed by a practice session consisting of one trial. The specific task was to type the direction in two digit format of thirty six randomly presented runways into a laptop keyboard as quickly as possible after presentation. RT was measured from presentation to the first key press. On the second key press the next runway chart appeared. Even if an incorrect direction was typed the next runway appeared. SuperLab stored the RTs and identified incorrect responses although accuracy was not a variable under scrutiny. The independent variable was runway direction and the dependent variable was response time. All participants were debriefed and an informal interview was conducted during which they discussed their strategy for the task they had just completed. The data were transferred to SPSS 22 and Microsoft Excel for analysis.

6.4 EXPERIMENTAL METHOD (EXPERIMENT TWO)

6.4.1 PARTICIPANTS

Twenty current airline pilots all currently flying moving map equipped aircraft were recruited on an opportunity basis. All the pilots had in excess of 5000 hours of airline experience, so could be considered uniformly experienced. No payment was involved.

6.4.2 APPARATUS

This experiment also utilised approach charts modified and presented to participants using the same protocol as experiment one. The same equipment and software were employed except that for methodological reasons a remote keypad was used rather than the laptop keyboard.

6.4.3 STIMULI

Stimuli consisting of sixteen separate runway depictions on a realistic approach chart (See Figure 6.3) were loaded onto a laptop computer and presented in *north up* portrait orientation. The charts were of a format that the participants were very familiar with. The following modifications were performed using Adobe Photoshop software. The rotation tool in Adobe Photoshop enabled the accurate rotation of the runway depictions in 45º stages. For each of these eight orientations, two separate charts were prepared, resulting in sixteen charts. A realistic depiction of terrain either left or right of the approach centreline as viewed from final approach was added to each chart such that for each orientation there were two charts, one depicting terrain on the left and one depicting it on the right. Excess detail was removed from each chart to avoid distraction from the spatial judgment task. The experiment was compiled using Superlab 5 software. The depictions were randomised and the software was configured to capture response time with millisecond accuracy.

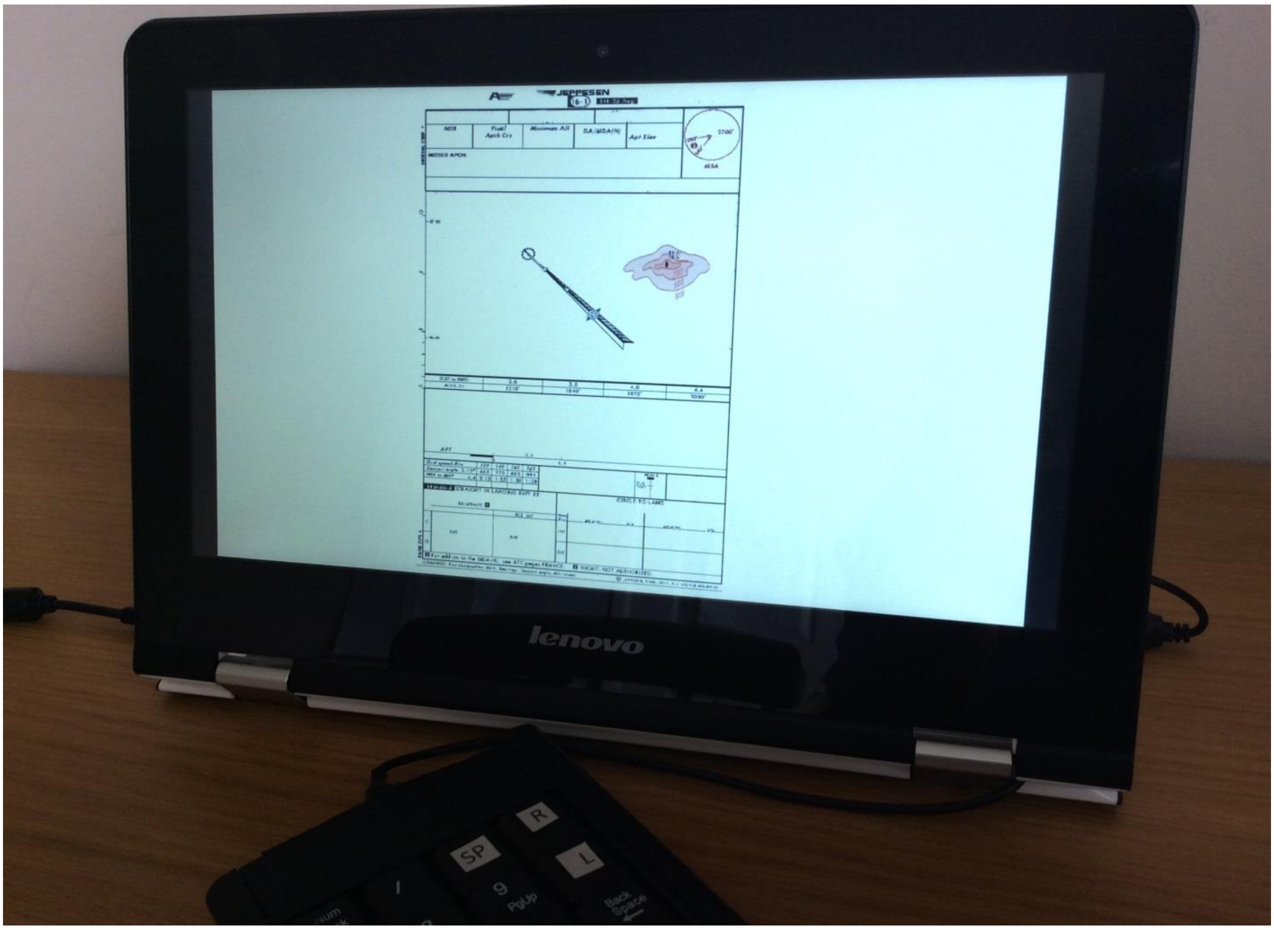


Figure 6.3: The laptop computer and remote keypad used in experiment two showing the runway and terrain depiction stimuli.

6.4.4 DESIGN AND PROCEDURE

Each participant completed a single block consisting of sixteen trials. The complete process took less than ten minutes. Participants were briefed verbally before the experiment and this was followed by a screenshot on the laptop reiterating the verbal instructions, this was followed by a practice session consisting of one trial. The experimental task was to judge whether the terrain depicted on the chart was located to the left or right of the runway centreline from the perspective of a pilot aligned with the runway. Participants were required to respond as quickly as possible by pressing either a left or right key on a remote keypad. The left and right keys were arranged in the vertical plain to avoid any Stroop effect between the presented stimuli and the keyboard orientation. Response time was measured from stimulus presentation to the key press. After a short delay the next runway chart appeared even if the incorrect key was pressed. SuperLab stored the response times and identified incorrect responses. The independent variable was runway direction and the dependent variable was response time. All participants were debriefed and a facilitative interview was conducted during which they discussed their strategy for the task they had just completed.

6.5 THE CONTEXTUAL CUEING RESEARCH

6.5.1 EXPERIMENT THREE: THE ALERT/INDICATION HYPOTHESIS EXPERIMENT

EXPERIMENTAL METHOD

6.5.2 PARTICIPANTS

The participants were forty current airline pilots from several airlines. Twenty participated in each condition. The participants were informed that their performance during the simulated session would be assessed and the results analysed. No personal information regarding individual pilots was collected. It was a condition of participation that minimal personal data regarding individual pilots would be collected.

6.5.3 APPARATUS

Four full flight simulators were used for the experiment. A repeatable scenario fully representative of a real flight was achievable. The visual system enabled instrument conditions to be simulated. The scenario was run in real time and took approximately five minutes to complete.

6.5.4 PROCEDURE

The experiment utilised a between-participants design with twenty pilots in each experimental condition (*n*=40). This approach was adopted in order to control for practice effects. In the control condition each participant experienced a *corrective* TCAS RA requiring a climb or descent, whilst in the experimental condition the flight crew experienced a *preventive* TCAS RA in level flight which required no change to the aircraft's flightpath. A realistic and repeatable scenario was simulated for the experiment. Figure 6.4 shows an incorrectly flown TCAS preventive RA as indicated on the aircraft primary flight display. It can be seen from the vertical speed indicator on the right hand side of the instrument that a descent has been initiated, whilst the alert required the aircraft to remain at 7000 feet. The data collected related to the accuracy of the TCAS manoeuvre in each experimental condition. These data were transferred to an excel spreadsheet and analysed in SPSS.

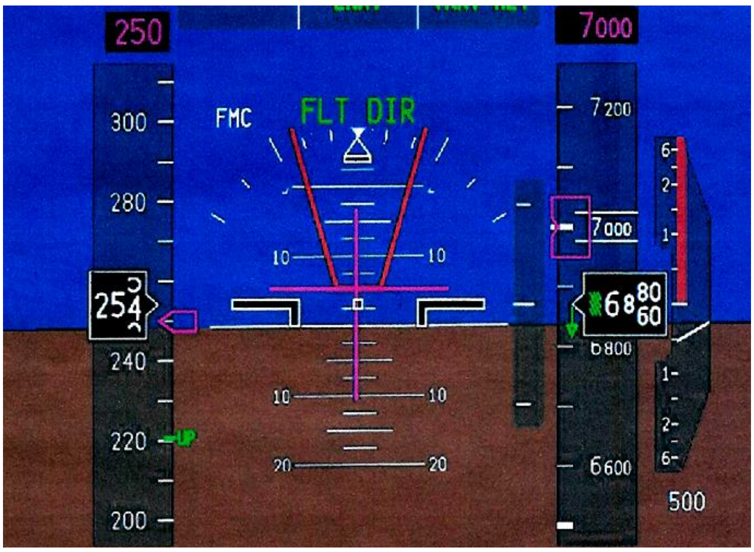


Figure 6.4: An incorrectly flown TCAS preventive RA

6.6.1 EXPERIMENT FOUR:

THE SYSTEM CONFIGURATION CONTEXT HYPOTHESIS EXPERIMENT

6.6.2 EXPERIMENTAL METHOD

The participants were twenty four current airline flight crews from several airlines. Each participant was informed that their performance during the simulated session would be assessed and the results analysed. No personal information regarding individual pilots was collected.

6.6.3 APPARATUS

Four full flight simulators were used for the experiment. A realistic visual scene was used. The visibility was good and the FCMs were oriented before the experiment started. The simulators exactly replicated the system status conditions that would be experienced on an aircraft.

6.6.4 PROCEDURE

The experimental hypothesis was that in contextual conditions that include an unusual system configuration there would be a significant increase in instances of misattribution of unrelated alerts and warnings to the influence of the unusual system configuration when compared to a normal system configuration. To test the experimental hypothesis a comparison was made of the accuracy of attributions made by flight crews who were aware of an unusual system configuration with those whose aircraft system configuration was normal before the alert. Some of the examples outlined in this thesis have included very serious misattribution errors such as omitting to extend the landing gear because there was a problem with the flaps but such scenarios are difficult to reproduce in a simulator. Given that the objective of experiment four was to examine the role of contexts involving unusual systems configurations in the misattribution of cause and consequential errors it was neither necessary nor desirable to use an overly complicated scenario. There are certain system configurations that, whilst not used every day, still qualify as a normal procedure. These less usual system configurations are usually accompanied by an indication to alert the flight crew to the altered system configuration. One such unusual configuration involves taxiing to and from the runway with one engine shut down in order to save fuel. Although this is both safe and approved by the regulator it is less than usual insofar as the system configuration generates alert/s that would otherwise not be present. Experiment four simulated this type of system configuration. In the control condition the participants responded to a routine alert that there was no reason to expect, whilst in the experimental condition the aircraft was operating in a system configuration resulting in related alert/s that the flight crew would be expecting to occur. In the control condition there was an expectation in this experiment that the checklist would be completed. The one-tailed hypothesis was that in the experimental context condition the flight crew would perform either no analysis of the alerts or less complete analysis than in the control condition where no alerts were expected. The criterion for deciding whether analysis had taken place was whether the flight crew completed the corresponding checklist or chose to omit it because they attributed the alert to the unusual system configuration. The experiment generated quantitative data that were analysed in SPSS.

6.7 THE SITUATIONAL CONTEXT RESEARCH

6.7.1 RESEARCH DESIGN

This research chose the phenomenon of the "landing gear retracted approach" to examine the role of situational context in SFP occurrences. The research was literature review based, involving the gathering of specific data from a wide range of sources. The occurrence literature was searched using multiple search terms to identify instances of airliners that had been flown to a late stage of the final approach with the landing gear retracted in error. Such an occurrence meets the necessary criteria to be categorised as an instance of SFP. On the basis of the narrative reports, several recurrent features of the situational context that prevailed in advance and at the time of the occurrence were examined. Statistical analysis was performed and a preliminary taxonomy of the resultant situational features was developed.

6.7.2 PROCEDURE

An extensive review of the accident/incident literature revealed instances of landing gear retracted landings involving public transport aircraft in countries including the UK, USA, Canada, Australia, Russia, Spain and others, so this is a worldwide phenomenon. It emerged that in many of these instances, features of the situational context were similar. For this research, situational context was defined as the situational conditions prevailing at the time of the occurrence; this could include geographical position, air traffic environment, in fact almost any environmental condition not encompassed by the previous hypotheses. The diverse nature of the reporting protocols, the age of some of the reports and the different types of aircraft involved meant that any dataset based upon worldwide data would be very difficult to analyse, although this was attempted. For this reason the NASA ASRS database was used as the primary source for the gathering of qualitative data. The rationale for this decision was that whereas the NASA ASRS yielded in excess of one hundred potential occurrences at a first pass, other sources only resulted in isolated instances. Nonetheless, in addition to the twenty three instances from ASRS, two quite recent significant reports from the Australian ATSB (ATSB, 2009b and ATSB, 2010a) were included in the dataset; these isolated instances were located by a detailed examination of all relevant instances in most of the accident databases worldwide. This research is confident that the majority of reported occurrences have been located. Although the dominance of the ASRS database may appear to present a USA centric bias, background, research indicated that the phenomenon being examined followed a similar pattern whether it occurred in the USA, the UK, Australia, Russia, Spain or anywhere else. Furthermore, the ASRS data used included two instances that occurred in the UK, one from Mexico and one from Japan. Several potential instances were excluded from the dataset due to lack of relevant information. There were also a few instances where the flight crew reported intentionally flying at a low height with the landing gear retracted; these were also excluded. Because instances where the aircraft actually lands with the landing gear retracted are very rare, this study examined the data relating to instances of flight crews who only avoided such an event because the aircraft's warning system alerted them. To enable more detailed analysis it was also decided to consider only two of the most produced families of airliners, the Boeing and Airbus families, although there was clear evidence from the incidents cited earlier in this thesis that this phenomenon afflicted other types as well. Restricting the data in this way also assisted the researcher in identifying the technical aspects involved. Deciding on the search terms required the researcher's insight into the language and phrases a pilot would use when reporting such an occurrence; a detailed understanding of the warnings generated by each type of aircraft in this context was also necessary to achieve this. For instance the term "too low gear" is a generic term whereas "config gear" is specific to certain Boeing aircraft. Table 6.1 is an Excel spreadsheet showing the final results of the ASRS search for reports for use in the situational context research.

ASRS REPORT	DATE	LOCATION	TYPE
500601	200102	Saint Louis	B757
521275	200108	Mexico City	A320
530057	200111	Dallas	B767
530272	200111	Dallas	B757
536528	200201	Providence	A320
598823	200311	Spokane	A320
612606	200404	Narita	B777
646532	200502	La Guardia	A319
677896	200511	Gatwick	B767
709648	200609	Atlanta	B757
741514	200706	Washington	A320
787444	200805	San Francisco	A319
793579	200807	Unspecified	A320
847845	200908	La Guardia	A320
897386	201007	Unspecified	B767
899943	201007	Los Angeles	A319
936266	201103	Heathrow	B777
1013802	201206	Calgary	A319
1145555	201401	Philadelphia	A319
1268264	201506	San Francisco	A319
1296951	201509	Unspecified	A319
1301258	201510	Philadelphia	A320
1416289	201701	Unspecified	B737

Table 6.1 The ASRS reports used in the situational context research

Figure 6.5 is a screenshot of one of the ASRS database searches where terms such as “too low gear” or “config gear” were entered. This process was repeated several times with multiple search criteria before all the relevant instances were identified. Because the narratives were the individual comments of the pilots involved it was necessary to read each report thoroughly to check for relevance. Although this process could not guarantee to locate every instance, given that over one hundred reports were examined, it is likely that the data set derived for this research is representative of the phenomenon.

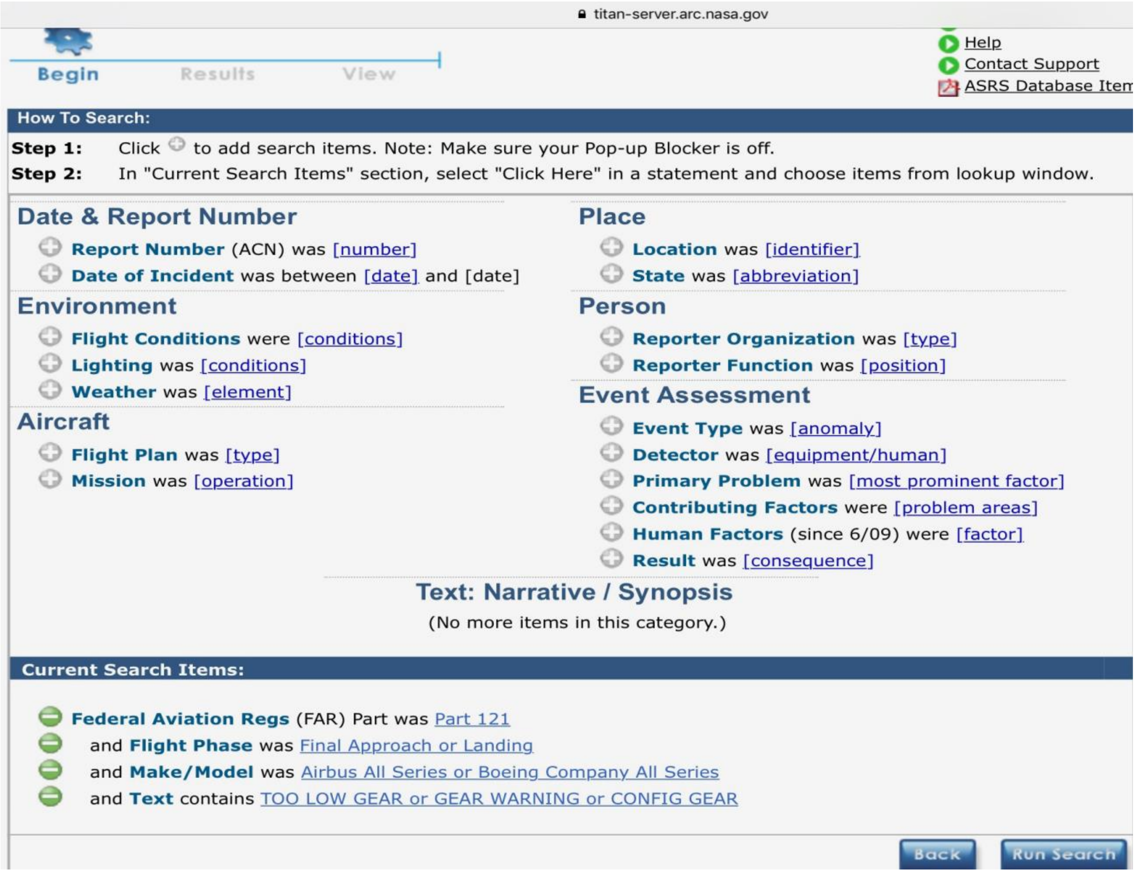


Figure 6.5: An ASRS database search illustrating some of the search items used in the situational context research

Because it was not possible to obtain data from final approaches that had proceeded without incident it was not appropriate to conduct experiments to test this hypothesis because a control condition could not be examined. An alternative strategy was to identify situational conditions that have prevailed in advance of a landing gear retracted approach and examine the reasons why the associated contextual features failed to alert the flight crew to their omission. This analysis would be incomplete if the underlying reasons that the flight crew reached a late stage in the approach with the landing gear retracted were not examined. Statistical testing was conducted to understand the relationship between these occurrences and the context prevailing in advance of the occurrence.

6.8 ETHICAL CLEARANCE STATEMENT

The research outlined in this thesis was conducted in accordance with the guidelines contained in the Loughborough University ethics approval statement.

PART III: THE RESEARCH AND RESULTS, ANALYSIS AND DISCUSSION

OVERVIEW

Chapters seven, eight and nine outline the research and experiments for the three research strands. Chapter seven explains how the conversation research became oriented towards institutional talk, in particular, impression management. The rationale for the research is explained with reference to the occurrence literature. The chapter proceeds to outline how the conversation-related data were obtained and how they were interpreted. Unlike the conversation research, unclear communication research was less amenable to experimental research so the linguistics literature was a primary source for explanations in this section. Chapter eight begins with a detailed explanation of how a pilot flying an aircraft equipped with state of the art map displays might still lose spatial awareness. Although this explanation is lengthy, it is essential to an understanding of the rationale for the research. Interwoven into this explanation is research that indicates that some of the spatial tasks undertaken by flight crews have complex neurobiological underpinnings that also need to be understood. Two experiments measured cognitive load and the results are discussed. Chapter nine examines the role of context in SFP in response to several safety occurrences that have shared contextual features. The premise of the contextual cueing study and its experiments was that the prevailing contextual conditions may have facilitated the flight crew's SFP. Three original hypotheses are outlined and tested and the results are discussed.

CHAPTER 7

THE VERBAL STRAND RESEARCH AND EXPERIMENTS

This chapter outlines the non-pertinent conversation (NPC) and unclear communication research.

7.1 EXPLAINING FLIGHT DECK CONVERSATION: A SURVEY AND REPORT

7.1.1 RESEARCH RATIONALE

Non-pertinent conversation (NPC) on the flight deck has been cited as a contributory factor in some of the most serious aviation accidents. However, as far as is known, the theoretical literature relating to conversation has never previously been employed to help understand why pilots sometimes converse at inappropriate times. The importance of this aspect of aviation related human factors is highlighted by the admission by the NTSB that the reasons why pilots sometimes behave in a too casual manner are unclear from their investigations (NTSB, 2010a. p. 110). The research objective was to identify the types of conversation that have been present in advance of an instance of SFP and to propose explanations for their use. By drawing upon multiple resources including those relating to impression management, personality and organisational behaviour, this study examined what might underlie some of the conversations that occur on routine flights. This focus upon routine non-accident flights was justified on the basis of evidence that routine flight deck conversations that are permitted by the regulations sometimes encroach into phases of flight where they are prohibited. It was emphasised in the Buffalo report (NTSB, 2010a) that today "for sterile cockpit violations to be cited in an accident's probable cause crews do not have to be engaged in a conversation at the time the accident sequence commences, the conversation just has to be present at some point during the flight". The current ethnographic study involved surveying current airline pilots regarding their opinions on the underlying purpose of a range of conversation types that they have experienced on the flight deck. These conversation types were derived from a thematic analysis (TA) of several carefully chosen CVR transcripts of airline crews conversing in advance of an accident. For the purposes of this study TA can be considered as a qualitative analytic method for: ‘identifying, analysing and reporting patterns (themes) within data, which minimally organises, describes and interprets the dataset in respect of various aspects of the research topic (Braun & Clarke, 2006 p. 79). Pre-testing of the questionnaire developed for this study confirmed that routine flight deck conversations are similar to those heard in advance of the accidents considered in this study; furthermore such conversations share much in common with conversations in other institutional settings. Twenty eight recurrent conversation types were categorised using seven possible explanation categories. Because this research was unable to locate any directly relevant literature relating to the airline context, it integrated existing insights from research related to impression management, organisational citizenship behaviour (OCB) and personality with expertise from individuals who have actually heard such conversations, in a preliminary attempt to understand why these recurrent conversation types occur. If it could be shown that patterns exist in the way flight deck conversations are interpreted it would support the notion that the NPC is a researchable phenomenon. Furthermore, given that the questionnaire conversation types and the motives for their use were based upon existing literature it should be possible to propose underlying reasons for their occurrence.

7.1.2 INTRODUCTION TO THE FLIGHT DECK CONVERSATION STUDY

This study emerged out of two fatal accidents that prompted the NTSB to include the avoidance of distraction on their “Most Wanted List” of safety improvements in 2016 (NTSB, 2016).The narrative surrounding these accidents indicated that the reasons why pilots inadvertently distract themselves by conducting non-pertinent conversations were unclear. The necessary raw data are usually available in the wake of an accident because flight deck recordings are made. Also the study of conversation is highly developed, albeit not in the aviation context. These two factors indicated that it should be possible to propose some explanations that might assist in mitigating the effects of this current and persistent threat to aviation safety. In recent years the topic of pilot professionalism has become the focus of critical attention from both the industry and the travelling public alike. At the forefront of this focus have been instances where pilots have broken the rules relating to non-pertinent conversations (NPCs) at critical times. In the USA and most other countries, the sterile cockpit rule prohibits pilots from conducting any conversations not related to the operation of the aircraft at any time whilst it is moving on the ground and whilst airborne below ten thousand feet. The four accidents chosen as the basis of this study all involved pilots who infringed this rule, a factor that was considered by the investigators to have contributed to the accident. In two of the instances the aircraft were on the ground and the conversation occurred once the pilots erroneously believed they had completed all the necessary actions to operate safely. In one case the flaps had been incorrectly extended, and in the other the pilots failed to navigate accurately to the correct runway. The two other instances involved aircraft in flight and one report noted that the crew had “squandered time and attention, which were limited resources that should have been used for attending to operational tasks” (NTSB, 2010a, p. 93) a criticism that could be applied to each of the accidents under consideration in this section of the thesis. In addition to investigating the distractions caused by conversation, investigators frequently draw conclusions relating to the professionalism of the flight crew based on the content and tone of what was heard. In the transcript of the Lexington accident flight crew the captain is heard to use the phrase “at your leisure” several times during flight preparation, and in the transcript of a flight crew at St Louis the captain commented that he was “ambivalent” due to his impending retirement (NTSB, 2009 p. 72). In each of these cases the investigation attached negative connotations to what was said but this study adopts the perspective that whilst only the speaker knows absolutely what was intended to be conveyed, the next best insight is likely to come from individuals who have experienced similar conversations in the same environment. Evidence from the transcripts indicated that running a relaxed flight deck is a highly valued group norm,[vii] in which case the phrase “at your leisure” takes on a far more positive connotation. Nonetheless, no operations manual would encourage the use of such terminology so there is some evidence that group norms sometimes conflict with organisational norms. In this case an examination of the interactions between institutional features of the airline context and aspects of personality that have been noted in airline pilots is essential. Research indicates that airline pilots tend to prefer to think of themselves as autonomous actors in their professional life (See Bennett 2010) but the reality is that they are quite restricted in their actions. Bennett referred to this as the “paradox of control”. Gergen & Taylor (1969) suggest that presenting oneself in ways that are inconsistent with expected values can be an effective strategy for the maintenance of an individual’s sense of autonomy. Viewed from this perspective, presenting oneself as “ambivalent” as the captain at St Louis did, is less likely to be an “offhanded comment” as judged in the report (NTSB, 2009, p. 72), than a strategically motivated one with foundations in both group personality and organisational context. The importance of this proposal is that the former attribution defies either explanation or solution whilst the latter can at least be explained (See Hill and Buss, 2008, p. 64) and defences devised. This study’s aim of identifying the underlying reasons behind some of the most recurrent flight deck conversation topics has potential to address some of the questions posed in the report into the Lexington accident; firstly, whether the “too casual behaviour” exhibited by this flight crew is normal and is likely to be exhibited by other flight crews, and secondly, why the pilots behaved as they did (NTSB, 2010a, pp. 110-113). Obtaining answers to these types of questions would be facilitated by this study's aim of providing a repository for all that is known about phenomena such as the NPC.

7.1.3 COCKPIT VOICE RECORDING

The cockpit voice recorder (CVR) is a device that records flight deck noises from a range of sources including the pilots' transmissions on the radio, talk between the pilots and general sounds within the cockpit. There are very few aspects of cockpit operations which are not captured by the CVR. For instance, flap and landing gear selection both make recognisable sounds. All CVRs record on a loop which continually erases the recording after a specified time. The rationale behind erasing the tapes is controversial to some but it is an accepted protocol that pilots' conversations on routine flights should not be scrutinised. When an accident occurs, the CVR stops and the tape can be retrieved. In cases where there is a serious incident but no accident, the CVR may not automatically stop; in these cases the pilot must deactivate the CVR manually by tripping a circuit breaker. Because assessment of the severity of an incident can be subjective it is not uncommon for crews to omit to do this, causing the incident recoding to be overwritten and the data lost. The previously cited *wrong runway* incident at Lulea was an example of a very serious incident which was not reported until the CVR had been overwritten. Because CVR tapes are only accessible under the conditions just outlined they provide limited data relating to behaviour on normal flights except to the extent that an accident flight is normal until the accident.

7.1.4 RATIONALE BEHIND THE CHOICE OF TRANSCRIPTS

The NTSB accident database was the source for most of the accident data for this research for a number of reasons. Although the standard of aviation accident investigation worldwide is very high, there are features of the NTSB's approach that outweigh the disadvantages of an exclusively American perspective. NTSB reports are uncommon insofar as they assign each accident a “probable cause” whereas many investigating agencies specifically avoid doing this. Also the NTSB usually provides complete cockpit recordings, which is rarely the case elsewhere. For this research, all public transport accidents in which damage, injury or death had occurred for the ten year period preceding the start of 2013 were examined. These accident reports were narrowed down to those in which the word “conversation” was present in the description of the event. All of these reports were examined and a subjective assessment of whether the conversation was an important factor was made. This step was essential to capture accidents in which the investigation had mentioned a conversation but had not included it as a contributory factor or a conversation had occurred but it played no part in the accident. Only four accident reports included CVR transcripts that were complete enough and contained enough detail to be useful for this research. Each of the related accident investigations considered that the presence of conversation had been a factor in the accident. These four transcripts were analysed and themes were identified. The themes from the four transcripts provided the ideas necessary to develop the taxonomy of flight deck conversation applied to a range of transcripts examined in this research. Details of the four transcripts used are shown in Table 7.1 below.

Table 7.1: The four accident reports examined during theme development

The Buffalo Accident (NTSB, 2010a)	
Colgan Air operating as Continental Connection 3407: Bombardier Dash 8 Q400, N200WQ Clarence Center, New York. February 12th 2009.	Loss of control on final approach
The Lexington Accident (NTSB, 2007a)	
Comair 5191: Bombardier CL 600, N431CA: Lexington. August 27th 2006.	Wrong runway takeoff resulting in collision with terrain
The Kirksville Accident (NTSB, 2006a)	
Corporate Airlines 5966: BAE Jetstream, N875JX: Kirksville, Missouri. October 19th 2004.	Collision with terrain on final approach
The Charleston Accident (NTSB, 2010c)	
PSA 2496: Bombardier CL600, Charleston, West Virginia. January 19th 2010.	Incorrect takeoff configuration resulting in runway overrun

7.1.5 RESEARCH INVOLVING FLIGHT CREWS AT WORK

Clearly all the FCMs involved in the occurrences examined in this study were at work at the time so it is important to examine the strengths and limitations of research based upon such evidence. Firstly, it should be noted that almost all investigating agencies caution against drawing wider conclusions on the basis of such data. For this reason the investigation reports used extensively in this study have been used only to the extent necessary to provide ideas that have been elaborated upon by a range of experimental methods. Many of the extracts of conversation have been modified slightly to make them more understandable, for instance if colloquial or unacceptable (#) language is used. Typical alterations were the replacement of “sorta” with “sort of” or insertion of punctuation.

Opinion is divided upon the value of qualitative data obtained from the flight deck. Some consider the flight deck environment so complex that something important might be missed or an observer may simply be unaware that a particular behaviour is important (Brannick, Roach and Salas, 1993: 306, cited in Bennett, 2010), whilst others consider that meaningful data relating to work can only be obtained in the real work setting. These conflicting arguments were at the forefront of planning this research although since these arguments were first made, the scope for observing on the flight deck has diminished greatly. In addition to the impossibility of conducting observations on the flight deck due to security restrictions there are other methodological issues that arise when an observer is present on the flight deck. It was noted in the Buffalo accident report that professional observers conducting in-flight safety audits have commented that the behaviour they see on such flights may not represent what occurs on unobserved flights (NTSB, 2010a: p. 101). Given that even these highly trained observers express doubt regarding the reliability of flight deck observations, the data obtained by such studies would appear to be of limited use. One alternative to observing would be to ask a pilot’s opinion upon a particular phenomenon, but reliability issues occur here as well. Harvey and MacDonald (1993: p. 77) discuss how respondents are likely to contaminate the answers they give to researchers by responding in ways that they believe the researcher wants to hear. In several of the reports examined for this research, peers were called upon to voice an opinion about a colleague who had been involved in an accident; comments were without exception positive, or if a criticism was offered it was always mitigated. This observed inclination to avoid criticising a colleague may be founded in the “reciprocity norm”, or the tendency to avoid saying something negative about someone else lest someone say similar things about you. Evidence from this research indicated that pilots appeared to be constrained by the need to avoid conflict and avoid saying the wrong thing to the wrong person, or in mixed company (See NTSB, 2010a, p. 194). The dominant strand seemed to involve the avoidance of topics that might in some way be detrimental to one’s personal interests. These initial observations suggested that the flight deck context would be a strong candidate for socially desirable responding. This meant that it was intuitively unsound to ask pilots to comment upon their own behaviour, so the novel approach adopted for this study was for the researcher to provide pilots with an example of someone else’s behaviour and ask their opinion about that. The four transcripts proved to be a rich source of examples of recurrent verbal behaviours but the researcher was conscious of the ethical difficulties of attributing subjective meanings retrospectively to recorded transcripts; for this reason the transcripts used for this study only acted as a springboard to provide ideas relevant to the general area of interest. The issue of subjectivity was also important because those best qualified to understand the airline context, including the researcher conducting this study, are also those likely to have the most strongly formed opinions on a given type of behaviour. During the detailed literature review it was concluded that even a non-pilot with extensive aviation experience would encounter difficulty interpreting some of the jargon used by pilots, so there was no alternative to conducting most of this research with airline pilots despite the possibility that objectivity might suffer. To control for this, wherever possible, survey data and experimental results were validated or challenged by data from unstructured interviews where participants provided their views on the phenomena under examination.

7.1.6 ACCESS TO FLIGHT CREWS

This has become a particular challenge in recent years due to increased security measures. When flight crews report for work they are often in restricted areas with no public access. Furthermore, they are usually time pressured and unlikely to be willing to devote the necessary time to requests to complete a survey. Some airlines prohibit their flight crews from discussing details of their work environment and even where this is not the case, flight crews might be wary of unintentionally divulging some sensitive information about that environment. Some pilots might also be suspicious of research into their human limitations. One of the overriding obstacles to overcome was to convince potential participants that there was some value to the research that warranted their participation. For this research, flight crews were approached on an opportunity basis as they reported at a training facility where they were undergoing either recurrent checks or conversion training. This venue had the advantage that the security restrictions were more relaxed and the pilots were under considerably less time pressure but they were still *in role,* an important aspect in relation to their professional identity discussed later.

7.1.7 RECURRENT FEATURES OF VERBAL BEHAVIOUR IN THE FLIGHT DECK EVIDENT IN THE TRANSCRIPTS

Detailed thematic analysis of the four subject transcripts indicated that pilots were sociable and interested in learning about their colleague(s). <u>First officers</u> spoke about career advancement, including leaving the airline, without inhibition; captains also spoke of changing airlines but with less conviction. Sociability and politeness were hallmarks of conversation within the flight deck but there were several examples of direct and indirect criticism of outsiders, including managers, other airlines and pilots from other bases, different cultures and nationalities. There was a high level of agreement between pilots, and disagreements were usually trivial and easily rectified. Three of the transcripts made reference to aspects of the speakers' home life; in some cases in considerable detail. None of the transcripts included any active attempt to discourage a conversation during sterile cockpit periods although pilots usually stopped conversing when the cognitive demands of the operation required.

7.1.8 INITIAL DEVELOPMENT OF A MODEL OF FLIGHT DECK CONVERSATION USE

7.1.8.1 ITEM CONSTRUCTION

As an initial step in the process of identifying the dominant characteristics of flight deck conversations, a selected extract from the Buffalo accident transcript (NTSB, 2010a, pp. 199-202) was chosen. This seminal accident was chosen because in addition to the distracting effect of the conversation experts have drawn inferences relating to professionalism, skill levels, and even the truthfulness of some of its content. The six minute transcript extract, which gave no hint that it occurred in an aviation context, was presented by a third party to three psychologically naïve participants with no particular knowledge of aviation. Their task was to read the transcript and answer three questions:

- How do you visualise these two individuals?
- Where do you think this conversation is taking place?
- What do you think the conversation is about?

Unstructured interviews with the three assessors indicated that they thought the conversation was more detailed than usually heard in a casual setting so was likely to have occurred in a work related setting. When asked how they visualised the two individuals involved in the conversation, they all thought, on the basis of some of the phrases used, one of the speakers was younger than the other speaker. They also noticed that the apparently junior speaker agreed quite a lot and seemed to be going along with the conversation out of politeness. The conversation was about a successful career that ended in redundancy. They all commented upon the one sided nature of the conversation but noted that it seemed friendly. What emerged was a picture of hierarchically ordered conversation dominated by a superior, likely to have been enacted in an institutional setting. Although this brief fragment of conversation was towards the extreme end of what has been heard in transcripts in terms of detail and length, its similarities with other flight deck conversations suggests that intentionally or not, an impression is conveyed during such conversation. Official investigations into the four accidents that provided the themes for this research concluded that the verbal behaviour on each of the transcripts constituted unprofessional behaviour so it is clear that investigators feel qualified to make subjective inferences based upon common sense judgments of flight deck conversation. This also implies that investigators and others (such as managers and regulators) have a clear notion of what constitutes professional discourse and what does not. None of the pilots who behaved unprofessionally in these accidents had a reputation for being unprofessional so it appears that they somehow misinterpreted how language conveys professionalism. The aim of this study was to determine whether NPCs were researchable and if so, to identify the underlying reasons these distracting conversations take place with a view to mitigating their effect.

A reasonable starting point for such a study is found in some common ground in each of the four transcripts; that is the sociability evident between the FCMs. In line with many institutional contexts, sociability is not a requirement for operating an airliner; in fact if all pilots complied rigidly with the sterile cockpit rule the flight deck would not be a very sociable place at all. So being sociable is likely to be to some extent strategically deployed. Later in this thesis some of the motivations that might underpin the need to establish and maintain a positive self-image in the interests of psychological well-being are outlined. Central to this need is the notion of “face” as defined by Erwing Goffman in the 1960s and elaborated upon many times since. According to Goffman, “face” is concerned with the positive social value a person seeks to claim for oneself during an interaction, achieved by acting in ways that portray them in a positive light. This view of “image” as predominantly related to how one feels about oneself (one’s self-concept), although very relevant to this study, has been overshadowed in recent years by an increased interest in how individuals seek to control how others think of them. What is being described here is impression management (IM), which although having its origins in the psychology literature (Schlenker, 1980; Riess et al., 1981; Schneider, 1981) is now widely researched in institutional settings. Given that the study of IM has been applied to occupations as diverse as dental surgeons (Evans et al., 2005) and American presidents (Tetlock, 1981) among others, it is reasonable to speculate that researching IM in flight crews might be useful in explaining flight deck conversations. Research involving accountancy firms has used the concept of IM to explain discretionary narrative disclosure in reporting of information strategically selected by managers to display and present…information in a manner intended to distort readers’ perceptions of corporate achievements (Godfrey et al., 2003, p. 96:). Although IM has not been specifically cited as a factor in an airline accident, as long ago as 1991 the investigation into an accident at Detroit (NTSB, 1991b) identified an instance of a first officer exaggerating his previous experience in such a way that his captain could have been overly impressed by his capabilities. The report concluded that this behaviour was both unethical and unprofessional (Ibid., p 53). This was not an isolated instance of the phenomenon; the account provided in conversation with his first officer by the captain involved in the accident at Buffalo (NTSB, 2010a), whilst not an untrue account of his professional history, gave no hint to his addressee of the multiple difficulties he had encountered on his way to, and whilst occupying the captain's seat. These and other examples from the aviation literature prompted a detailed review of the IM literature (e.g. Jones and Pittman, 1982; Tedeschi and Melburg, 1984; Becker and Martin, 1995) in search of similar instances of IM to those evident in the transcripts. It was concluded that Bolino and Turnley's (1999) 44 items identified as IM tactics used in organisations were sufficiently similar to some of the verbal behaviour evident in many of the transcripts used in this research to provide the initial themes that would be searched for in the four transcripts. The initial 44 items and their assigned categories are shown Table 7.2 below.

Table 7.2:

Impression management: adapted from Bolino & Turnley, 1999.

SELF-PROMOTION (SP)
Make people aware of your accomplishments
Try to make a positive event that you are responsible for appear better than it actually is
Try to take responsibility for positive events, even when you are not solely responsible
Try to make a negative event that you are responsible for appear less severe than it actually is
Display your diplomas and/or awards that you have received
Let others know that you have a reputation for being competent in a particular area
Make public your talents or qualifications
Declare that you have other opportunities outside your current job
Talk about important people that you know
Try to distance yourself from negative events that you were a part of

INGRATIATION

Praise people for their accomplishments

Do personal favours for people

Offer to do something for someone that you are not required to do

Compliment people on their dress or appearance

Agree with a person’s major ideas or beliefs

Take an interest in a co-worker’s or supervisor’s personal life

Imitate others’ behavior or manner

Spend time listening to people’s personal problems even if you have little interest in them

EXEMPLIFICATION

Arrive at work early in order to look dedicated

Work late at the office so that others see you

Try to act like a model employee

Volunteer to help whenever there is the opportunity

Pretend to be busy even if you might not be

Make sure you are never seen wasting time.

Arrange things on your desk so that it looks like work is being done

Let others know how much overtime you work

INTIMIDATION

Yell at people

Have “showdowns” with co-workers or supervisors

Threaten a co worker

Make people aware that you can control things that matter to them

Punish people when they do not behave as you would like

Insult or put down your co workers

Try to embarrass people in front of their peers or supervisors

Try to appear unapproachable or distant

SUPPLICATION

Intentionally do poorer quality work than you are capable of

Advertise your incompetence in a particular area or about a particular issue

Pretend to not understand something that you do understand

Play “dumb.”

Ask for help or assistance that you really do not need

Try to appear helpless or needy

Ask a lot of questions

Downplay your accomplishments

Let others win arguments

Try to agree with people even when you might disagree

The 44 items in Table 7.2 represent the initial item pool of conversation types used in this study of flight deck conversation. In a replication of Bolino and Turnley’s method, the current research developed two taxonomies, one of flight deck conversation types and the other of the potential motives underlying them. Data from existing researcher outlined by Jones and Pittman (1982) were modified in response to interviews with subject matter experts (SMEs) to more accurately represent the aviation context. Although many of the behaviours suggestive of IM in the transcripts were oriented towards the needs of the speaker, during the thematic analysis of the transcripts it became clear that some of the conversations related to work could also fulfil an altruistic function such as setting a good example to subordinates or simply offering them support or encouragement in their professional life. Bolino and Turnley's work facilitated the examination of this idea by illustrating the overlap between IM and a construct known as organisational citizenship behaviour (OCB). They note that OCB, in common with other citizenship behaviours is believed to have its foundations in both personality and attitude. OCB is thought to be characterised by a disposition towards co-operation and helpfulness coupled with a tendency to reciprocate the actions of the organisation. Although due to the overlap with IM, the taxonomy developed for this research proposes no motives for strategic flight deck conversations that are exclusively founded in OCB research, OCB did provide a framework to propose more altruistic explanations than would have been possible if only IM had been considered. For instance, the example of a captain who loaned a manual to a colleague in the Buffalo transcript (NTSB, 2010a, p 194) could readily be categorised as an instance of ingratiatory behaviour from an IM perspective, whereas Organ (1988) provides a framework that extends beyond the individual's need to the needs of the wider organisation as illustrated below:

ALTRUISM: This concerns helping a colleague in completing his or her task under unusual circumstances.

CONSCIENTIOUSNESS: This refers to an employee performing his or her job in a manner above that which is expected.

CIVIC VIRTUE: This involves actively supporting the administrative functions of the organisation.

Viewed from an OCB perspective an explanation for loaning a manual that focused solely upon the ingratiatory value to the loaner would be likely to provide an incomplete explanation.

Given that the majority of conversations in the transcripts were characterised by friendliness and cooperation at least between the two collocutors, it was important to establish a basis for this observation in personality research. NASA research by Fitzgibbons et al. (2004) indicates that pilots tend to score in the middle ranks in terms of extraversion and agreeableness (two dimensions of the widely used general personality inventory, NEO PI-R). From these limited data it was possible to propose a behaviour type which, for the purposes of this research, has been named "normal friendliness" and is proposed to account for any verbal behaviour that could only be understood as motivated by friendliness, cooperation or both. Although the normal friendliness category may seem ill-defined, the seemingly random remarks that have preceded aviation occurrences are among the most difficult to explain, and therefore represent an essential component of this study. In addition, during preliminary unstructured interviews, pilots repeatedly cited friendliness as a reason for flight deck conversations and commented that it would be out of the ordinary for a colleague to remain silent for extended periods. In summary, the initial lists of conversation types and possible explanations contained items based upon existing IM, OCB and personality research with some inevitable overlap between the three. In order to modify these initial lists to accurately reflect the airline context a modification of Hinkin's (1998) procedure for development of this type of measure was used.

7.1.8.2 ITEM REDUCTION PROCESS AND PRETESTING

STEP 1: ITEM GENERATION

The starting point for producing an item pool of flight deck conversation types was Bolino and Turnley's (1999) list of 44 conversation types indicative of IM. Because of the overlap between IM and OCB it was unnecessary to add any new items for the latter because several items suggestive of OCB were already included. No items for "normal friendliness" were added because this was an original construct with no detailed information on what types of verbal behaviour it would attract, merely a description.

STEPS 2 AND 3: QUESTIONNAIRE ADMINISTRATION AND ITEM REDUCTION

Hinkin (1998) suggests that a questionnaire be administered at this stage of the research but for a number of reasons it was decided to conduct face to face unstructured interviews with assessors with relevant experience for this stage. The rationale for this was that several of the 44 items in Table 7.2 could immediately be discarded because they were not expressed verbally. Other items were clearly irrelevant to the aviation context, but an overriding requirement was to address the issue of availability of high quality participants by making the best use of those available. Those participants involved in item reduction would not be available for the final questionnaire because of their involvement in its construction, so it was necessary to gain the maximum amount of information from the minimum number of participants at this pretesting stage. At the end of this preliminary stage there were 36 conversation types in the item pool. These 36 items were presented to a group of three airline instructors each with a human factors qualification, with the instruction to identify any of the behaviours they had never encountered on the flight deck. At this stage they were not concerned with the motives behind the conversation types, simply whether they were recognisable. At the end of this process there was agreement about 30 items. Stone (1978) has commented upon the absence of any generally accepted quantitative index of content validity of psychological measures, noting that judgment should be exercised when validating a measure. The first step in establishing content validity was to randomise the list of 30 conversation types and present the list to an opportunity sample of five current airline pilots with the instruction to identify any of the behaviours which they had never encountered on the flight deck. This process resulted in the removal of a further two items and some minor rewriting. A further opportunity sample of pilots (*n=5)* assessed the list until there was unanimous agreement that all the items were recognisable in a flight deck context. To establish inter rater reliability, a sample of pilots (*n=4)* involved in the item reduction process were asked how frequently they had observed each of the 28 conversation types, responding on a five point Likert scale with one representing "never observed this behaviour" and five representing "regularly observed this behaviour". These data were collected on an Excel spread sheet and analysed in SPSS. Table 7.3 indicates a Cronbach's Alpha of .955 representing a very high level of interrater agreement regarding the prevalence of the conversation types.

Table 7.3: Inter-rater agreement related to content validity of the items

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.955	.952	Reliability Statistics

The responses to this final stage of pretesting confirmed that none of the twenty eight conversation types attracted a score of one on the Likert scale, indicating that all the participants had observed each of the conversation types in the questionnaire on at least one occasion. Content validity was continually monitored during questionnaire administration by carefully examining whether any of the items in either taxonomy were considered ambiguous by respondents. There was no evidence that participants failed to recognise any particular conversation type or explanation of motive. Table 7.4 is the list of conversation types developed from the processes described above.

Table 7.4: A list of flight deck conversation types

Mentioning an occasion when a favour was done for a colleague or the organization
Mentioning how a rule was stretched in the interests of the organization
Ranting about a controversial subject
Agreeing with your opinion despite initially appearing to disagree (back-pedalling)
Mentioning impressive possessions such as boats, cars or houses
Making random non-operational remarks (e.g. visibility, landmarks)
Exaggerating the role they played in a positive event in which they were involved
Mentioning important or influential people they know professionally or personally
Sharing a confidence with you
Mentioning higher status achieved in a previous occupation (e.g. military rank/management role)
Offering flattery to you (e.g. saying they enjoy flying with you)
Downplaying their reliance upon their current employer for employment
Commenting positively or negatively on other pilots' or airlines' style or standards
Sympathising or empathising with you
Mentioning their professional accomplishments
Offering an excessively detailed account of how they come to occupy their current professional role

Mentioning the early age or impressive timescale within which a qualification or promotion was achieved

Expressing cynicism relating to the organisation

Mentioning events that emphasise the importance of family life to them

Mentioning their preference for a relaxed operating style, personally or in others

Expressing opinions and attitudes that mirror your own

Mentioning, even indirectly, their high remuneration or wealth

Commenting on their lowly position in the organisation and its effect on them

Mentioning that they turned down a seemingly attractive job elsewhere

Displaying an interest in aspects of your personal life of which they have no knowledge

Mentioning an occasion when they accepted unnecessary inconvenience in the interests of a colleague or the organisation

Downplaying the importance of a negative event in which they were involved

Mentioning that they have professional opportunities outside their current job

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The next stage involved proposing potential motives behind the 28 flight deck conversation types in the list above. In a replication of Jones and Pittman (1982) a preliminary taxonomy based upon a wide variety of IM behaviours identified by earlier researchers was developed. Significant modification was undertaken in order to accurately represent the aviation context. Jones and Pittman's (1982) taxonomy identified five theoretical groupings of IM strategies that individuals commonly use. These included: self-promotion, whereby individuals point out their abilities or accomplishments in order to be seen as competent by observers; ingratiation, whereby individuals use flattery or do favours to elicit an attribution of likeability from observers; exemplification, whereby people self-sacrifice or go above and beyond the call of duty in order to gain the attribution of dedication from observers; intimidation, where people signal their power or potential to punish in order to be seen as dangerous by observers; and supplication, where individuals advertise their weaknesses or shortcomings in order to elicit an attribution of being needy from observers. The aviation context required a qualitatively different taxonomy of motives to the one developed by Jones and Pittman. The same opportunity sample of pilot assessors *(n=5)* who were involved in item reduction were asked to assess Jones and Pittman's five theoretical groupings in terms of their relevance to the aviation context. They considered that supplication was unrecognisable in the aviation context despite clear evidence of its presence in at least two of the transcripts. They also considered that Jones and Pittman's description of intimidation was more extreme than they could envisage although they did recognise the potential for intimidation on the flight deck. It was decided that supplication would not be included as a potential motive and intimidation would be included but with references to punishment or danger replaced by terms such as overawe or unsettle. The next stage was to ensure the items were contextually plausible, which was achieved by modifying the items in the list to make them recognisable in the flight deck context. For instance, there were no instances of pilots self-promoting by declaring how skilled they were, but there were many examples of discourse that would support that inference. Potential examples from the transcripts include several accounts relating to a speaker's ability to walk into another job with ease, their high level or diverse type of experience, the speed of their career progression and others. Not all accounts alluded to success; the pervasiveness in the transcripts of accounts of behaviour, often justifying a speaker's actions meant that self-justification (SJ) was considered an essential motivating strategy. According to Scott and Lyman (1968) justifications are accounts in which one accepts responsibility for the act in question, but denies the pejorative quality associated with it. Notably, they comment that accounts are "situated" according to the statuses of the speakers and are standardized within cultures so that certain accounts are routinely expected when activity falls outside the domain of expectations. This means that not only the nature of justifications is predictable within a certain culture but that their occurrence is probably a requirement of interaction within that culture. One further motivation category “crew cohesion” was developed to explain the prevalence of downward directed IM in the transcripts. The literature relating to charismatic leadership (Gardner & Cleavenger, 1998; Leary, 1989) speculates that charismatic leaders may use IM to create a transformational image to their subordinates. In terms of assigning a motive, research by Rozell and Gundersen (2003) found that ingratiation and exemplification increased feelings of cohesiveness within the group. Attempting to present oneself as likeable would help team members be attracted to one another, thereby increasing cohesion. This observation coupled with Organ’s (1988) notion of OCB supported the idea that making an effort to appear likeable could be underpinned by the objective of maintaining a cohesive team. A final motive that could not be ignored was the pursuit of normal friendliness through conversation. Although this phenomenon is by far the most difficult to define and research, it was the single most frequently offered explanation for flight deck conversation given during unstructured interviews conducted in pre testing, so had to be included. In addition to the seven items just outlined, participants would be offered an option of providing an alternative explanation of their choice during the survey. Table 7.5 is the list of motives developed for this research including four of the strategies outlined by Jones and Pittman and three further strategies developed during pre-testing.

Table 7.5: A list of seven possible motives for flight deck conversations.

SELF-PROMOTION

Where individuals point out or allude to their abilities or accomplishments in order to be seen as competent, successful and autonomous

INGRATIATION

Where individuals use flattery or excessive self-deprecation to appear likeable to colleagues

EXEMPLIFICATION

Where individuals describe self-sacrificing or going above and beyond the call of duty in order to appear dedicated to their work

CREW COHESION

Where conversation is enacted to reinforce the impression that the speaker belongs to a like-minded group to the listener

SELF-JUSTIFICATION

Where conversation is enacted to explain and justify some aspect of the speaker's situation or actions; this can involve selective omission or inclusion of relevant information

INTIMIDATION

Where conversation tends to overawe, unsettle or invoke a sense of inferiority or inadequacy in you, either personally or professionally

NORMAL FRIENDLINESS

Where conversation is enacted in the interests of normal social interaction, characterised by co-operation and agreeableness; speakers are neither excessively introverted nor extraverted in such interactions

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7.1.9 SURVEY RESULTS

The survey results are shown in Table 7.6 below. The final number of pilots who responded to the survey was 37, made up of 15 first officers and 22 captains. 50 pilots were approached to participate representing a response rate of 74%. 70.3 % of respondents were aged 40 or over and 29.7% were under 40. This was a representative age demographic for major airlines but because pilots often progress from commuter airlines to major airlines, commuter airlines may tend towards a higher proportion of younger pilots.

Table 7.6: The flight deck conversation survey questionnaire results summary

Survey overview: Number of respondents: 37. Expected number of respondents: 50

Response rate: 74.0%

The results from the survey are presented below question by question.

Section 1: About You

1. Which age range applies to you?		
Under 40 years old:	29.7%	11
40 years old and over:	70.3%	26

2. Your rank is?		
First Officer:	59.5%	22
Captain:	40.5%	15

Section 2: Flight deck Conversation Questionnaire.

1. Mentioning an occasion when a favour was done for a colleague or the organisation Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	45.9%	20.0%	32.95%
Ingratiation:	0.0%	8.6%	4.30%
Exemplification:	32.4%	20.0%	26.20%
Crew cohesion:	8.1%	11.4%	9.75%
Self-justification:	2.7%	20.0%	11.35%
Intimidation:	0.0%	0.0%	0.00%
Normal Friendliness:	10.8%	20.0%	15.40%

2. Mentioning how a rule was stretched in the interests of the organisation Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	25.0%	20.6%	22.80%
Ingratiation:	2.8%	5.9%	4.35%
Exemplification:	33.3%	26.5%	29.90%
Crew cohesion:	2.8%	11.8%	7.30%
Self-justification:	36.1%	26.5%	31.30%
Intimidation:	0.0%	8.8%	4.40%
Normal Friendliness:	0.0%	0.0%	0.00%

3. Ranting about a controversial subject (e.g. politics or industrial relations etc.) Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	33.3%	17.2%	25.25%
Ingratiation:	5.6%	3.4%	4.50%
Exemplification:	2.8%	3.4%	3.10%
Crew cohesion:	16.7%	24.1%	20.40%
Self-justification:	5.6%	17.2%	11.40%
Intimidation:	19.4%	27.6%	23.50%
Normal Friendliness:	16.7%	3.4%	10.05%
Other explanation	Possibly expressing an personal agenda relating to an industrial issue		3.4%

4. Agreeing with your opinion despite initially appearing to disagree (back-pedalling) Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	0.0%	0.0%	0.00%
Ingratiation:	54.5%	22.6%	38.55%
Exemplification:	0.0%	0.0%	0.00%
Crew cohesion:	30.3%	38.7%	34.50%
Self-justification:	6.1%	3.2%	4.65%
Intimidation:	6.1%	0.0%	3.05%
Normal Friendliness:	3.0%	35.5%	19.25%

5. Mentioning impressive possessions such as boats, cars or houses Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	74.3%	15.6%	25.25%
Ingratiation:	0.0%	15.6%	4.50%
Exemplification:	0.0%	0.0%	3.10%
Crew cohesion:	0.0%	6.2%	20.40%
Self-justification:	2.9%	0.0%	11.40%
Intimidation:	8.6%	21.9%	23.50%
Normal Friendliness:	14.3%	31.2%	10.05%
Other explanations	Participants thought this varied considerably with individual personality		1.8%

6. Making random non-operational remarks (e.g. visibility or landmarks) Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	5.7%	3.8%	4.75%
Ingratiation:	2.9%	7.7%	5.30%
Exemplification:	0.0%	0.0%	0.00%
Crew cohesion:	8.6%	50.0%	29.30%
Self-justification:	2.9%	7.7%	5.30%
Intimidation:	0.0%	3.8%	1.90%
Normal Friendliness:	77.1%	19.2%	48.15%
Other explanations	Seeking confirmation that a colleague is alert Sounding out a colleague's ideas and opinions Thinking out loud		5.3%

7. Exaggerating the role they played in a positive event in which they were involved Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	79.4%	10.3%	44.85%
Ingratiation:	0.0%	0.0%	0.00%
Exemplification:	5.9%	20.7%	13.30%
Crew cohesion:	0.0%	10.3%	5.15%
Self-justification:	8.8%	48.3%	28.55%
Intimidation:	5.9%	6.9%	6.40%
Normal Friendliness:	0.0%	3.4%	1.70%

8. Mentioning important or influential people they know professionally or personally Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	68.6%	23.3%	45.95%
Ingratiation:	5.7%	3.3%	4.50%
Exemplification:	0.0%	3.3%	1.65%
Crew cohesion:	0.0%	6.7%	3.35%
Self-justification:	2.9%	16.7%	9.80%
Intimidation:	20.0%	36.7%	28.35%
Normal Friendliness:	2.9%	10.0%	6.45%

9. Sharing a confidence with you Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	9.1%	3.0%	6.05%
Ingratiation:	27.3%	24.2%	25.75%
Exemplification:	0.0%	3.0%	1.50%
Crew cohesion:	15.2%	24.2%	19.70%
Self-justification:	9.1%	12.1%	10.60%
Intimidation:	3.0%	0.0%	1.50%
Normal Friendliness:	36.4%	27.3%	31.85%
Other explanations 3%	Advice seeking and expressing trust in the addressee		3.0%

10. Mentioning higher status achieved in a previous occupation (e.g. military rank or management role) Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	79.4%	10.0%	44.70%
Ingratiation:	0.0%	3.3%	1.65%
Exemplification:	2.9%	3.3%	3.10%
Crew cohesion:	0.0%	6.7%	3.35%
Self-justification:	8.8%	30.0%	19.40%
Intimidation:	5.9%	33.3%	19.60%
Normal Friendliness:	2.9%	10.0%	6.45%
Other explanations:	Seeking self-esteem		1.7%

11. Offering flattery to you (e.g. saying they enjoy flying with you) Choose your primary explanation for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	2.9%	0.0%	1.45%
Ingratiation:	50.0%	16.1%	33.05%
Exemplification:	0.0%	0.0%	0.00%
Crew cohesion:	17.6%	32.3%	24.95%
Self-justification:	0.0%	0.0%	0.00%
Intimidation:	0.0%	0.0%	0.00%
Normal Friendliness:	29.4%	51.6%	40.50%

12. Downplaying their reliance upon their current employer for employment Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	57.6%	10.7%	34.15%
Ingratiation:	0.0%	0.0%	0.00%
Exemplification:	0.0%	7.1%	3.55%
Crew cohesion:	6.1%	32.1%	19.10%
Self-justification:	21.2%	17.9%	19.55%
Intimidation:	12.1%	7.1%	9.60%
Normal Friendliness:	3.0%	7.1%	5.05%
Other explanations	Previous experiences of unreliable employers Discomfort at being so reliant upon employer for financial security		9.0%

13. Commenting positively or negatively on other pilots' or airlines' style or standards Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	20.6%	11.5%	16.05%
Ingratiation:	5.9%	7.7%	6.80%
Exemplification:	8.8%	0.0%	4.40%
Crew cohesion:	20.6%	38.5%	29.55%
Self-justification:	20.6%	0.0%	10.30%
Intimidation:	2.9%	7.7%	5.30%
Normal Friendliness:	17.6%	34.6%	26.10%
Other explanation	Participant highlighted the difference between positive and negative comments. Also commented that this behaviour was often linked to the individual's personality		1.5%

14. Sympathising or empathising with you Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	0.0%	0.0%	0.00%
Ingratiation:	34.4%	20.0%	27.20%
Exemplification:	0.0%	0.0%	0.00%
Crew cohesion:	25.0%	43.3%	34.15%
Self-justification:	0.0%	0.0%	0.00%
Intimidation:	0.0%	0.0%	0.00%
Normal Friendliness:	40.6%	33.3%	36.95%
Other explanation	Used as a means of encouraging a co worker		1.7%

15. Mentioning their professional accomplishments Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	84.8%	0.0%	42.40%
Ingratiation:	0.0%	6.7%	3.35%
Exemplification:	3.0%	10.0%	6.50%
Crew cohesion:	0.0%	6.7%	3.35%
Self-justification:	0.0%	26.7%	13.35%
Intimidation:	3.0%	23.3%	13.15%
Normal Friendliness:	9.1%	23.3%	16.20%
Other explanation	Used as a means of rebalancing status when faced with a self-promoting co worker		1.7%

16. Offering an excessively detailed account of how they come to occupy their current professional role Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	66.7%	13.8%	40.25%
Ingratiation:	0.0%	0.0%	0.00%
Exemplification:	9.1%	10.3%	9.70%
Crew cohesion:	0.0%	10.3%	5.15%
Self-justification:	18.2%	31.0%	24.60%
Intimidation:	0.0%	17.2%	8.60%
Normal Friendliness:	6.1%	17.2%	11.65%

17. Mentioning the early age or impressive timescale within which a qualification or promotion was achieved Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	94.1%	6.9%	50.50%
Ingratiation:	0.0%	3.4%	1.70%
Exemplification:	2.9%	10.3%	6.60%
Crew cohesion:	0.0%	3.4%	1.70%
Self-justification:	0.0%	24.1%	12.05%
Intimidation:	2.9%	48.3%	25.60%
Normal Friendliness:	0.0%	3.4%	1.70%

18. Expressing cynicism relating to the organisation or its management Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	3.2%	18.5%	10.85%
Ingratiation:	3.2%	0.0%	1.60%
Exemplification:	3.2%	3.7%	3.45%
Crew cohesion:	48.4%	3.7%	26.05%
Self-justification:	16.1%	29.6%	22.85%
Intimidation:	6.5%	18.5%	12.50%
Normal Friendliness:	16.1%	18.5%	17.30%
Other explanations:	Personal dissatisfaction Distrust of management due to previous employment experiences		5.4%

19. Mentioning events that emphasise the importance of family life to them Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	20.6%	18.5%	19.55%
Ingratiation:	2.9%	0.0%	1.45%
Exemplification:	0.0%	11.1%	5.55%
Crew cohesion:	14.7%	25.9%	20.30%
Self-justification:	14.7%	11.1%	12.90%
Intimidation:	0.0%	0.0%	0.00%
Normal Friendliness:	47.1%	33.3%	40.20%

20. Mentioning their preference for a relaxed operating style, personally or in others Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	17.6%	6.7%	12.15%
Ingratiation:	5.9%	16.7%	11.30%
Exemplification:	5.9%	0.0%	2.95%
Crew cohesion:	32.4%	36.7%	34.55%
Self-justification:	20.6%	6.7%	13.65%
Intimidation:	0.0%	0.0%	0.00%
Normal Friendliness:	14.7%	33.3%	24.00%
Other explanations:	Captains often do this on the first leg to set a relaxed tone for the flight/pairing		1.4%

21. Expressing opinions and attitudes that mirror your own Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	0.0%	3.3%	1.65%
Ingratiation:	54.5%	16.7%	35.60%
Exemplification:	0.0%	0.0%	0.00%
Crew cohesion:	27.3%	36.7%	32.00%
Self-justification:	0.0%	3.3%	1.65%
Intimidation:	0.0%	0.0%	0.00%
Normal Friendliness:	18.2%	40.0%	29.10%

22. Mentioning, even indirectly, their high remuneration or wealth Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	79.4%	12.5%	45.95%
Ingratiation:	0.0%	0.0%	0.00%
Exemplification:	2.9%	3.1%	3.00%
Crew cohesion:	0.0%	3.1%	1.55%
Self-justification:	11.8%	18.8%	15.30%
Intimidation:	5.9%	53.1%	29.50%
Normal Friendliness:	0.0%	9.4%	4.70%

23. Commenting on their lowly position in the organisation and its effect on them Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	6.2%	0.0%	3.10%
Ingratiation:	25.0%	28.0%	26.50%
Exemplification:	9.4%	4.0%	6.70%
Crew cohesion:	12.5%	28.0%	20.25%
Self-justification:	25.0%	20.0%	22.50%
Intimidation:	0.0%	0.0%	0.00%
Normal Friendliness:	18.8%	12.0%	15.40%
Other explanations:	Looking for sympathy Expressing dissatisfaction with their lot		5.55%

24. Mentioning that they turned down a seemingly attractive job elsewhere Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	64.7%	18.5%	41.60%
Ingratiation:	2.9%	3.7%	3.30%
Exemplification:	2.9%	11.1%	7.00%
Crew cohesion:	2.9%	7.4%	5.15%
Self-justification:	23.5%	37.0%	30.25%
Intimidation:	0.0%	11.1%	5.55%
Normal Friendliness:	2.9%	11.1%	7.00%

25. Displaying an interest in aspects of your personal life of which they have no knowledge Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	2.9%	0.0%	1.45%
Ingratiation:	17.6%	14.3%	15.95%
Exemplification:	0.0%	0.0%	0.00%
Crew cohesion:	26.5%	42.9%	34.70%
Self-justification:	0.0%	0.0%	0.00%
Intimidation:	0.0%	0.0%	0.00%
Normal Friendliness:	52.9%	42.9%	47.90%

26. Mentioning an occasion when they accepted unnecessary inconvenience in the interests of a colleague or the organisation Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	35.3%	28.6%	31.95%
Ingratiation:	2.9%	7.1%	5.00%
Exemplification:	50.0%	14.3%	32.15%
Crew cohesion:	2.9%	14.3%	8.60%
Self-justification:	0.0%	25.0%	12.50%
Intimidation:	0.0%	3.6%	1.80%
Normal Friendliness:	8.8%	7.1%	7.95%

27. Downplaying the importance of a negative event in which they were involved (e.g. interview, conversion course or examination) Choose your primary explanation for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	8.8%	40.0%	24.40%
Ingratiation:	8.8%	12.0%	10.40%
Exemplification:	5.9%	4.0%	4.95%
Crew cohesion:	2.9%	8.0%	5.45%
Self-justification:	67.6%	20.0%	43.80%
Intimidation:	0.0%	0.0%	0.00%
Normal Friendliness:	5.9%	12.0%	8.95%
Other explanation:	Self-esteem maintenance		2.05%

28. Mentioning that they have professional opportunities outside their current job (e.g. different airline or profession) Choose your primary and secondary explanations for this behaviour.			
Conversation type	Primary Explanation	Secondary Explanation	Average
Self-promotion:	73.5%	11.1%	42.30%
Ingratiation:	0.0%	7.4%	3.70%
Exemplification:	2.9%	0.0%	1.45%
Crew cohesion:	0.0%	0.0%	0.00%
Self-justification:	11.8%	37.0%	24.40%
Intimidation:	2.9%	22.2%	12.55%
Normal Friendliness:	8.8%	22.2%	15.50%

Table 7.7 below outlines the two taxonomies developed for this research. The seven main categories are the motives for conversation derived from the explanations provided by the participants ranked in order of recognisability. For instance, 25% of the total dataset was recognisable as self-promotion. Figure 7.1 illustrates the percentage distribution of conversation motives graphically. The second taxonomy ranks each of the 28 conversation types within their motive category. For instance, “mentioning the early age or impressive timescale within

which a qualification or promotion was achieved" was the most recognisable manifestation of self-promotion in the dataset.

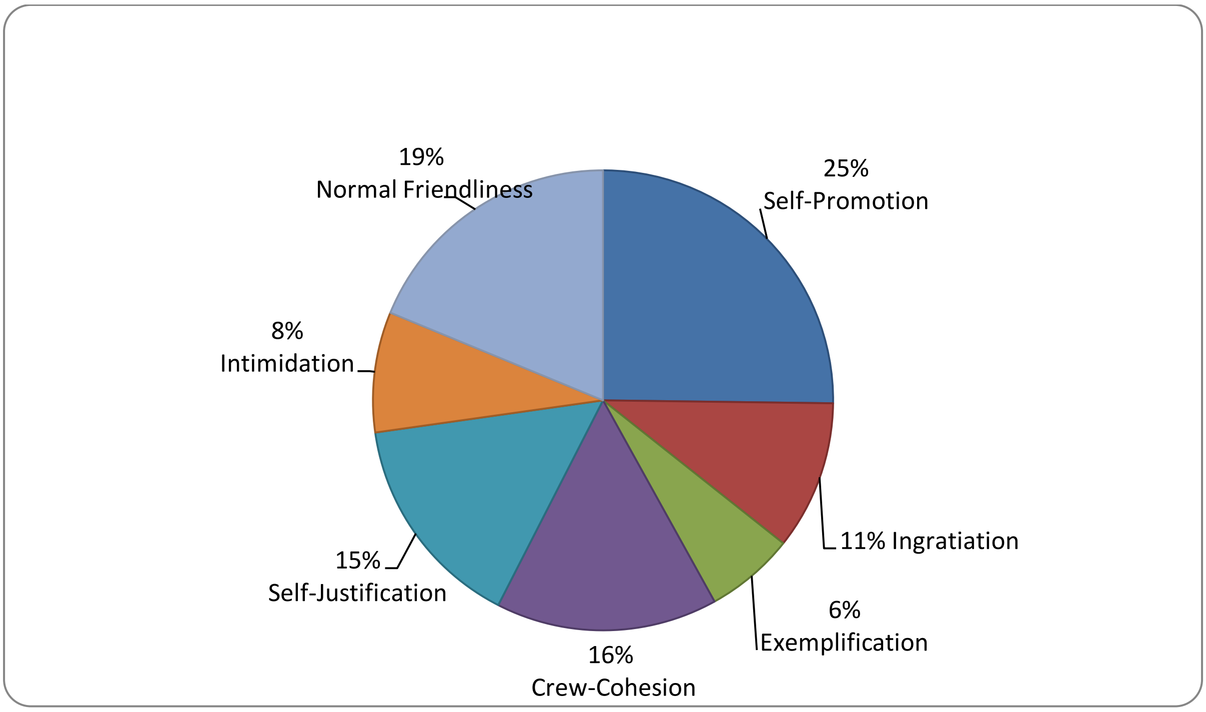


Figure 7.1

The percentage distribution of conversation motives derived from the questionnaire

Table 7.7:
Two taxonomies of strategic flight deck conversation ranked by recognisability of motive.

1. SELF-PROMOTION 25%	
Mentioning the early age or impressive timescale within which a qualification or promotion was achieved	50.50%
Mentioning important or influential people they know professionally or personally	45.95%
Mentioning, even indirectly, their high remuneration or wealth	45.95%

Mentioning impressive possessions such as boats, cars or houses	44.95%
Exaggerating the role they played in a positive event in which they were involved	44.85%
Mentioning higher status achieved in a previous occupation (e.g. military rank or management role)	44.70%
Mentioning their professional accomplishments	42.40%
Mentioning that they have professional opportunities outside their current job (e.g. different airline or profession)	42.30%
Mentioning that they turned down a seemingly attractive job elsewhere	41.60%
Offering an excessively detailed account of how they come to occupy their current professional role	40.25%
Downplaying their reliance upon their current employer for employment	37.75%
Mentioning an occasion when a favour was done for a colleague or the organisation	32.95%
Mentioning an occasion when they accepted unnecessary inconvenience in the interests of a colleague or the organisation	31.95%
Ranting about a controversial subject (e.g. politics or industrial relations etc.)	25.25%
2. NORMAL FRIENDLINESS 19%	
Making random non-operational remarks (e.g. visibility or landmarks)	48.15%
Displaying an interest in aspects of your personal life of which they have no knowledge	47.90%
Offering flattery to you (e.g. saying they enjoy flying with you)	40.50%

Mentioning events that emphasise the importance of family life to them	40.20%
Sympathising or empathising with you	36.95%
Sharing a confidence with you	31.85%
Commenting positively or negatively on other pilots' or airlines' style or standards	26.10%

3. CREW COHESION 16%

Displaying an interest in aspects of your personal life of which they have no knowledge	34.70%
Mentioning their preference for a relaxed operating style, personally or in others	34.55%
Agreeing with your opinion despite initially appearing to disagree (back-pedalling)	34.50%
Sympathising or empathising with you	34.15%
Expressing opinions and attitudes that mirror your own	32.00%
Commenting positively or negatively on other pilots' or airlines' style or standards	29.55%
Expressing cynicism relating to the organisation or its management	26.05%

4. SELF-JUSTIFICATION 15%

Downplaying the importance of a negative event in which they were involved (e.g. interview, conversion course or examination)	43.80%
Mentioning how a rule was stretched in the interests of the organisation	31.30%

5. INGRATIATION 11%	
Agreeing with your opinion despite initially appearing to disagree (back-pedalling)	38.55%
Expressing opinions and attitudes that mirror your own	35.60%
Offering flattery to you (e.g. saying they enjoy flying with you)	33.05%
Commenting on their lowly position in the organisation and its effect on them	26.50%
Sharing a confidence with you	25.75%

6. INTIMIDATION 8%	
Ranting about a controversial subject (e.g. politics or industrial relations etc.)	23.50%

7. EXEMPLIFICATION 6%	
Mentioning an occasion when they accepted unnecessary inconvenience in the interests of a colleague or the organisation	32.15%
Mentioning how a rule was stretched in the interests of the organisation	29.90%
Mentioning an occasion when a favour was done for a colleague or the organisation	26.20%

The results indicated that only in very few cases did participants describe a motive other than one of the seven conversation categories offered in the questionnaire, indicating that the survey reflected a realistic view of FCMs' experience of flight deck conversation. The pie chart at Figure 7.1 indicates how recognisable each explanatory category was in the complete dataset. For instance, 16% of the complete dataset was recognisable as being motivated by crew cohesion. From these data the seven explanation categories were ranked in the taxonomy. The decision to report the mean of first and second choices was to provide a more complete picture of the participants' assessments than was possible by only considering first choices. Although the second choice option was originally included so that participants would not feel pressured to choose a single explanation, upon analysis it was clear that some of the second choices produced only marginally lower percentages than the first choices. For instance, Category 11 related to flattery was considered to be motivated by normal friendliness by 51.6% as a first choice whereas 50% thought it was motivated by ingratiation as a second choice. Although averaging the scores in this way could be seen as a limitation of this research it was considered that this approach provided more accurate findings.

SELF-PROMOTION (SP)

Self-promotion accounted for the largest mean percentage of explanations relating to the motive for flight deck conversations. Furthermore, in most cases where SP scored highest, no other explanation exceeded the 95% confidence level set for this study. Exceptions to this included "ranting about a controversial subject", which although a low scorer in terms of SP, was an unexpected incumbent in this category given the apparent tendency towards conformity and attenuation of strong views that characterise flight deck interactions. The results indicate that this type of conversation is almost equally associated with "intimidation," a verbal phenomenon which despite being evident in some transcripts represented only 8% of the motivation explanations from the survey. Mentioning a favour done for a colleague or the organisation was thought to be motivated by “exemplification” as well as SP. There was some evidence of a recurrent link between SP and exemplification evident in an almost identical score for the two explanations for the “acceptance of unnecessary inconvenience in the interests of a colleague or the organisation”. Another apparent link was evident between conversations that emphasised autonomy such as “downplaying one’s reliance upon a current employer for employment”, or “mentioning a turned down job”. In addition to SP, both these explanations were considered to be motivated by. Each of the remaining SP explanations of motive were alone in reaching the inclusion criterion, indicating that they were highly recognisable to the survey respondents.

NORMAL FRIENDLINESS

An important but frustrating finding was that over 48% of respondents considered that the random type of conversations that have preceded so many accidents are no more than the pilots being friendly. Furthermore, only “crew cohesion” came close to meeting the statistical criterion for inclusion. This result is unsurprising given the documented failure to explain this type of conversation in the past. It did however, prompt this research to consider what might be achieved by the strategy of presenting as friendly; this is discussed later. Both confiding and flattering were also associated with ingratiation, and sympathising was considered to be motivated by crew cohesion as well as normal friendliness. Commenting on outsiders such as other airlines or pilot groups was also seen as friendliness although most of this type of conversation in the transcripts leaned towards the critical. There was however, one comment from a survey respondent who suggested that there was a considerable difference between the likely motive for a negative comment and a positive one. Whilst this is true, there were very few positive comments about out groups in the transcripts. Crew cohesion was the only other explanation for this type of conversation that met the inclusion criterion and was also the highest scoring explanation.

CREW COHESION

Crew cohesion was characterised by a preference for agreement. Although back-pedalling in a disagreement was attributed to this motive, ingratiation was a higher scorer. Expression of opinions that mirrored those of the listener attracted almost equal scores, divided between those who viewed it as cohesive and those who thought it was motivated by ingratiation. There was evidence that showing an interest in a colleague's life was considered cohesive behaviour. Cohesion was also expressed by comments relating to other pilots and airlines, also by critique of outsiders such as managers. It was noted earlier that expressions that signal a preference for a relaxed operation have attracted negative assessments in the accident literature; however, from the FCM's perspective they are mostly enacted in the interests of crew cohesion, with no close alternative explanation. This represents a conflict with the conventional wisdom expressed by investigators that relaxed or casual operations tend to signal a casual professional attitude. The closest non-qualifying category for expressions related to being relaxed was normal friendliness, which also provides few insights into why some FCMs fail to strike an acceptable balance between being relaxed/casual and behaving professionally.

SELF-JUSTIFICATION

Instances of FCMs downplaying their role in a negative event, such as failing an exam, were clearly identified as cases of self-justification. Less intuitively understandable is why mentioning that a rule had been stretched in the interests of the organisation would need justification. It is conceivable that avoiding appearing to be too closely allied to the management could be a motive given some of the cynicism expressed in the transcripts towards out groups including the management.

INGRATIATION

Ingratiation was characterised by a preference for conversation that reinforced similarity between speaker and listener, and certainly avoided disagreement. As previously stated, both confiding and flattering were considered to be ingratiation but both these conversation types were more associated with normal friendliness. An important finding relates to the expression of one's lowly position and its effect on the speaker. This was a category that respondents appeared not to recognise with much conviction despite at least two clear instances of accident flight crews commenting upon their lowly position in the organisation. One participant commented that such speakers might be seeking sympathy but overall the survey indicated that references to one's lowly position in the organisation were motivated by ingratiation.

INTIMIDATION

Intimidation did not feature prominently in the transcripts but where it did, its influence was considerable (See PCAA, 2010, p. 29: ATSB, 1995: NTSB, 1994, p. 57). Although ranting about politics etc. was considered by respondents to be intimidating, this was a lower scoring explanation than self-promotion and only a slightly higher scorer than crew cohesion. Whilst feeling intimidated is an intuitively predictable response to witnessing a rant, it may be that those who express extreme views by derogating an out group reinforce the cohesion of the in group in a "them and us" fashion.

EXEMPLIFICATION

The scores for exemplification were intuitively sound, with a bias towards recounting behaviour enacted in someone else’s interest. Explanations for accounts of rule stretching were almost equally distributed between self-justification and exemplification. Mentioning a favour done for a colleague or the organisation was predominantly associated with self-promotion although exemplification also met the inclusion criterion.

7.1.10 DISCUSSION OF THE FLIGHT DECK CONVERSATION RESEARCH

Whilst the four transcripts used for the initial construction of this research only provided limited evidence that self-promotion was prolific on the flight deck, the questionnaire responses and a more general review of other relevant transcripts confirmed this to be the case. Respondents were almost unanimous in their belief that when a pilot spoke or alluded to a command achieved at an early age or an impressive job obtained at an unusually low experience level, they were hearing self-promotion. The exchange below took place between the Buffalo accident flight crew:

Captain: *“but uh as a matter of fact I got hired with about six hundred and twenty five hours here”* (NTSB, 2010a, p. 277)

First officer: *“oh wow... that's not much for uh back when you got hired”* (Ibid., p. 278)

Whilst the majority of survey respondents reported being familiar with this type of conversation and interpreted it predominantly as self-promotion, there was also 26% who thought that such conversation was enacted with the intent to intimidate the listener. Emphasising one’s lack of experience at the time of achieving what is often the only promotion in a career may appear a counter intuitive self-promotion strategy to those unfamiliar with the airline context.

The media has a fascination with young airline pilots, with many instances of airline pilots claiming to be the youngest. In fact even the vice-chairman of the NTSB in 2008 dropped into one of his speeches that he became an airline captain at 27 [viii]so it is more than just intuition that this narrative exists. The accident literature clearly indicates that it is unwise to assume that just because an individual is appointed or promoted with low experience they must have exhibited exceptional skill. The extract above described how the captain had been hired at very close to the minimum experience and this perhaps invited the addressee to draw whatever conclusions she might on the basis of that information. In fact the report from which the extract was taken indicated that the speaker was actually an underperforming pilot for much of his career (NTSB, 2010a, p. 115). Connotations of ability seem to attach to those who achieve high professional status in aviation at an early age or in record time. This may stem from the requirement to achieve certain professional objectives within a specified timescale in settings such as the military or when being sponsored by an airline. Christopher Hart, the current NTSB Chairman, in his concurring statement regarding the Buffalo accident report (Ibid.) commented that in recent years the pilot demographic has changed markedly, with fewer military pilots entering the airlines, and whilst he acknowledged that a military background was not the only means of acquiring the requisite skills there was currently no effective system for ensuring unsuitable pilots reached airline flight decks. Given this heightened focus upon professional standards it is predictable that an underperforming pilot might engage in impression management.

Another important reason why SP may be such a prominent feature of flight deck conversation is that pilots are often meeting for the first time when they fly together. This was the case at Buffalo and Lexington and several of the other accidents cited in this research. When pilots first meet they need to make a positive impression in a very limited time, possibly even before they reach the aircraft. The investigation into the 1990 Detroit accident cited above (NTSB, 1991b) highlighted the dangers of pilots embellishing their experience with the objective of making a good impression at a first meeting, suggesting that assertive impression management has been identified as a risk in such contexts for a considerable time. Older first officers might consider it a priority to outline, sometimes indirectly, why they have not been promoted, whilst less experienced ones might embellish their experience to achieve better role congruity. Where a pilot has previously held a senior position in the military or elsewhere and now occupies a subordinate role, it could be a priority to offer an explanation for this situation. Although 19% of survey respondents found this type of conversation intimidating, the only documented instance of this phenomenon (the Detroit Accident) was more likely an attempt at self-justification than intentional intimidation. The Detroit accident cited above is a compelling example of the potential consequences of assertive impression management, which in this case resulted in a serious breakdown in the chain of command which led to a fatal runway collision. It is a feature of the airline context that extremely able and experienced pilots can find themselves occupying a subordinate role, sometimes for many years; as this situation is specific to the airline context, as far as is known there is no literature to directly support this explanation. Whilst not drawing a direct parallel, there is some similarity with Goffman's (1955) explanation of how embarrassing events compel people to engage in impressional (sic) strategies designed to counter their damaged image. A belief that one's social image is not what one would like it to be can prompt face saving strategies (Goffman called it "face work") such as "excuse making" and "role distancing". The captain in the Buffalo accident commented that he had turned down a seemingly attractive job flying a jet because of the terms of employment (NTSB, 2010a, p 204), thereby distancing himself from reliance on his current job, implying that he had successfully secured such a position, and providing a rational excuse for his continued presence in his current position. It should be pointed out that the transition from successfully operating a commuter turboprop aircraft like the one in the Buffalo accident, to operating a high performance jet is one that some pilots find challenging or impossible. This research indicated that FCMs identify this type of conversation primarily as self-promotion but to a lesser extent self-justification. The transcripts indicate that when pilots claim to have turned down jobs or downplay their reliance on their current job it is mostly interpreted as self-promotion. However, there are many rational reasons for staying in a current job that are unlikely to represent a speaker's chosen narrative. There are undoubtedly pilots who stay with their current airline as a risk avoidance tactic because they are aware that once incumbent in an airline, that organisation has an ongoing commitment to train them to proficiency in a way that would not necessarily be the case for a new hire who was not progressing normally. For obvious reasons, this represents an example of a type of explanation that a speaker is almost certain to avoid. In the extract below, the Buffalo (NTSB, 2010a, p. 205) captain describes how he represented himself at an interview:

"I told them I've flown the nineteen hundred and it would be a pretty easy transition"

Although this extract portrays him as confident and competent, his training records showed that, even though he completed all the necessary training, without a failure, the captain had experienced continuing difficulties with aircraft control, the aspect of his operation that was his downfall in the accident. Clearly a pilot with knowledge that he has a history of underperforming might seek to remain where he is but this poses a problem in a work environment where there is a recurrent narrative related to career progression, with both first officers and captains speaking of their ambitions to fly larger aircraft with major airlines. In two of the transcripts the pilots spoke of insurmountable obstacles to achieving those ambitions, thereby providing a plausible justification for staying where they were. The captain referred to above, spoke of moving to a larger airline but also acknowledged that he would need to revert to a first officer to achieve that objective. Where a previously high ranking individual is required to occupy a subordinate position there is some evidence that conversation can be strategically deployed to distance the speaker from that role. In the Detroit accident transcript (NTSB, 1991b) the first officer mentioned that he had been a high ranking officer in the military before joining his current airline employer (Ibid., p. 122). Furthermore there had been a number of job offers and this had not been his first choice (Ibid., p. 121). By enacting this conversation the speaker may have been asserting that although he was occupying the role of first officer, his colleague should not mistake him for someone who had only ever occupied the subordinate role. Such upsets of the normal flight deck hierarchy can have undesirable results as was the case in this accident. Although probably unintentionally, first officers tended to speak of gaining experience in their current commuter airline as a prerequisite step towards a career with a larger airline (NTSB, 2007a, p. 132; NTSB, 2010a, p. 251). From the perspective of a captain committed to remaining in a job that their subordinate considers just a stepping stone, this may represent a face threat. Both the captains at Lexington and Buffalo were faced with this type of conversation; the Lexington captain implied that as a captain he was not impressed with the first officer's salary he would have to accept if he were to move to the job proposed by the first officer. This is conceivably a type of defensive IM enacted to remind the first officer that what may be attractive for him could be seen as a retrograde step for a captain. In the Buffalo transcript the captain emphasised that as he started flying late in life, he would be faced with being a lifetime first officer if he went to a major airline. In reality, many captains would be reluctant to give up a command in order to move to a major airline but negative connotations can attach to individuals who appear too fond of being *in charge* and the transcripts indicate that such explanations are never heard. The status attached to being in command is almost a taboo subject but its influence is widespread. Being promoted to captain is for most pilots the only promotion they achieve in the span of their career but in most cases their progress towards it is largely outside their control. The topic of career progression was highly recurrent in flight deck conversations with first officers showing no reluctance to voice their promotion ambitions. Where captains spoke in the transcripts of their role they often downplayed the importance they attached to being a captain. Although captains spoke of their willingness to accept a demotion in order to fly a better aircraft for a larger airline, in reality these speakers were acknowledging that despite their powerful position as a captain they were relatively powerless in relation to the progress of their career. The topic of power and powerlessness is one that has interested psychologists for decades; as recently as 2014 researchers at Leiden University in the Netherlands provided evidence that when workers feel powerless they tend to go along with the very structures that reinforce their powerlessness for a range of reasons. In the Leiden research (Van der Toorn et al., 2015) considerable emphasis was placed upon legitimation due to workers' financial dependence. A captain who has met the required standards at one airline risks considerable financial risk if he goes to another airline and fails to meet their standards, so even if he would like to move, structural features of the way airlines recruit and retain pilots might make this impossible. Although there was plenty of resistance evident in the transcripts, most of the pilots who spoke of leaving had not done so. Resistance often seemed to take the form of denial; for instance, one captain who was approaching retirement commented in advance of an accident that he was "ambivalent" about aspects of his job, which was quite lazily interpreted by investigators as an indication of a casual attitude to his work. This naïve and reductionist interpretation of the comment ignores the influence that his powerlessness over his impending retirement may have had. Many pilots would like to continue flying after their imposed retirement age, as was demonstrated by a conversation that preceded an accident at Chicago (NTSB, 2007b, p. 189). Hill and Buss (2006) describe how the *feigning of disinterest* can be used as a strategy to disguise the envy that individuals may experience in relation to other colleagues in the face of a situational variable such as impending retirement that is outside their control. This tendency to downplay their powerlessness by diminishing the role of their employer in the control of their actions was ubiquitous in the transcripts with several instances of pilots downplaying their reliance upon their current job or their role in that job[ix]. This feigning of disinterest was incompatible with much of the other discourse in the transcripts, which was often characterised by a strong interest in career progression. The next section describes how the strategic use of language that emphasises the powerfulness of the individual in a situation where in reality they are not very powerful may operate below the level of human consciousness and provide an explanation for much of what is heard on the flight deck.

7.1.11 THE ROLE OF LOCUS OF CONTROL IN FLIGHT DECK CONVERSATION

The airline context is characterised by unequal power relations. Aside from those within the flight deck, pilots of all ranks live with a number of situational variables which tend to locate power in the relationship in the hands of others, such as the regulator or their employer. Pilots need to be self-assured in appropriate measure and the research indicates that this is probably the case. Joseph and Ganesh (2006) measured a construct known as “locus of control” which is a measure of the extent to which individuals believe they control the significant events in their lives. Individuals who believe they control the significant events in their lives possess a strong “internal locus of control” whilst those who believe such events are under external control have a strong “external locus of control”. The above research found that a sample of 101 Indian pilots (51 civilian, 50 military) were significantly more “internal” than the general population. In addition, civilian pilots had significantly higher internal ASLOC (aviation safety locus of control) (Hunter, 2002) scores than military pilots. Given this finding, airline pilots are left with a dilemma because even an optimistic interpretation of reality indicates that in their relations with their employer they occupy a relatively powerless position, an observation supported by the transcripts. Thus although they are expected to be in charge and make executive decisions on a routine basis, the conversations heard on the flight deck indicate that they are aware of this unequal power relationship. Most of the time, pilots work remotely from such influences but when they are reminded that their powerful position really only extends to the confines of the aircraft this can pose a real challenge to the identity they associate with their professional role. Where incongruence exists between an individual's sense of powerfulness (an accepted quantitative measure proposed by Osgood, May & Miron, 1975) and the environmental conditions being experienced, social stress is predictable. As previously stated, these challenges to the power of the pilots' role are not continuous but seem to be manifest in specific instances where they feel their ability to exercise the power they are accustomed to in their professional role is under threat. The transcripts indicate that pilots sometimes perceive such threats to their self-identity as coming from cabin attendants, engineers and schedulers among others. Mandler (1982) describes how interruptions to identity can result in autonomic activity in the form of stress, and Baddeley (1972) has described how stressors can cause the adaptive response of narrowing the attentional field to such crucial events. This model of reaction to stress explains some of the disproportionate responses to minor challenges to the powerfulness that apparently attaches to flight crews' identity when they are *in role*. One way of looking at the identity process is as a control system that defines the meanings attached to a given role (Burke, 1991). The transcripts indicate that pilots, particularly captains, routinely exercise power when in their professional role and inevitably this defines the standard or reference for who they feel they are when *in role.* Inputs from the environment are appraised and the appraisals are not always completely rational; for instance, the captain in the Kirksville accident appeared to view the inadvertent intrusion of a passenger's foot into the cockpit as sufficient challenge to his authority to cause him to drop a heavy manual on it (NTSB, 2006, p. 32). At the risk of overanalysing a seemingly trivial example of behaviour it is noteworthy that the exercise of power enacted by the captain was not a legitimate response in terms of his professional role so any sense he may have gained that he was powerful in the interaction in question was illusory. Nonetheless, although he may have felt powerful for a short time, his actions had no influence on the likelihood of such an intrusion occurring in the future. What he has achieved in the telling of the story is a sense that passengers are subordinate to him, which is only the case in very clearly defined contexts. There was a considerable amount of discourse in the transcripts which appeared to overstate the power and control that flight crews can exercise. In fact there is some evidence in the transcripts that pilots sometimes communicate anecdotes that either didn't actually happen (See NTSB, 1991a, pp. 52-53) or exaggerate their role with the objective of impression management. Although the Detroit report (Ibid., p. 53) considered such embellishment "inimical to flight safety", as long as these instances do not intentionally mislead a colleague in relation to some operationally relevant factor they are probably predictable on the basis that flight crews are expected to be powerful and to control events in their professional role and when threats to that power and control present themselves it is understandable that they might seek to minimise them. Furthermore, there is experimental evidence from Geer et al. (1970) indicating that even an illusory perception of control is enough to reduce autonomic responses to stressful stimuli. Burke (1991) developed a model of identity feedback (See Figure 7.2 below) which commences with an individual in a situational context: if this context matches with the individual's self-concept, all is well and no psychological discomfort is experienced. If, on the other hand, there is a mismatch between an individual's sense of powerfulness (*identity standard* in Figure 7.2) and the actual control they are able to exert in the current situation they are likely to experience psychological discomfort. Where this occurs in a situation that is unalterable it becomes necessary to adjust the way the situation is perceived until an accommodation is reached where one's self-concept and the situation can co-exist without psychological stress. Considerable evidence has now accumulated indicating a link between psychological stress and a range of autonomic responses such as cardiac sympathetic activation and elevated plasma catecholamine concentrations (Cacioppo et al., 1995). Effective stress coping is achieved when a stress response is activated on exposure to a stressful stimulus, but is quickly deactivated upon removal of the stimulus. Prolonged exposure or an inadequate response to stressful stimuli is thought to underlie most stress related mental disorders, such as depression or anxiety. Given that such disorders are the exception, it seems likely that most individuals are able to remove themselves from their situational stressors. Burke's model is illustrated in Figure 7.2.

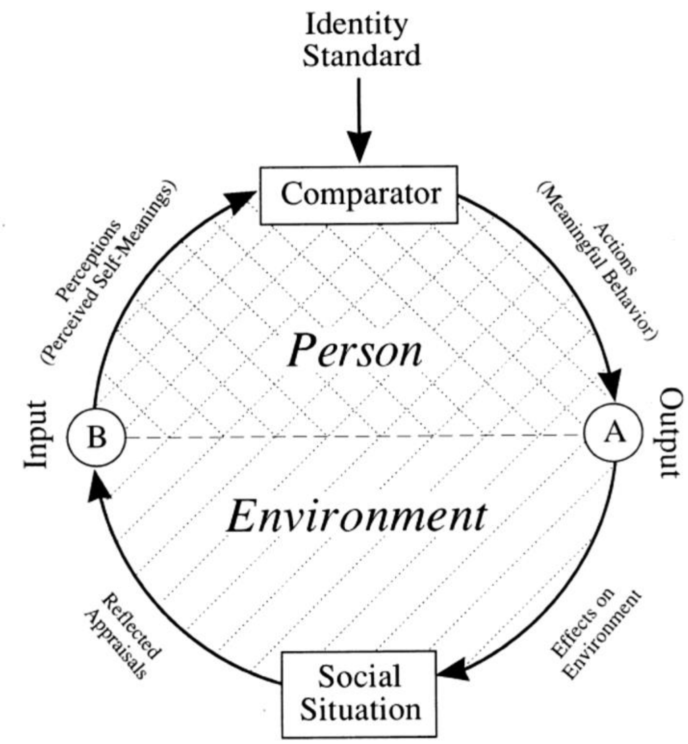


Figure 7.2: A self-identity feedback loop (Burke, 1991)

An explanation of Burke's (1991) feedback loop as applied to the NPC context:

1 An addressee receives a verbal input relevant to how they perceive their self-identity.

2. What is expressed is subject to a process of comparison and represents a mismatch with their identity standard, resulting in psychological discomfort.
3. To reduce this psychological discomfort the individual attempts to restore congruence between the identity standard they hold and the identity expressed at point B. If the environment is unchangeable then congruence will only be possible if she/he can modify their perception of the environment. This more congruent perception is represented by the output at Point A. The *social situation* at the bottom of the feedback loop represents the interactional environment. This is where the individual reassesses whether the attempts at congruence have been effective. If not, then psychological discomfort is likely to drive continued attempts to make the social environment and one's identity standard achieve congruence, in other words a long and strategically motivated narrative.

The transcripts provided many examples where something with the potential to be seen as a threat to the listener's self-identity was expressed. Below are some extracts from conversation from the Buffalo accident where the older captain and a young first officer talk about progressing to a major airline (NTSB, 2010a, p. 254); the captain starts:

"...at this point do I go to a major and you know not be able to be there for very long"…

The first officer replies:

"...yeah be a first officer the rest of your life…."

This was what Goffman (1967) referred to as a "dispreferred response" because of its potential to cause embarrassment or threaten status. The response highlights a number of relevant situational variables such as the recruitment and promotion limitations imposed by his age and his potential loss of status due to being a lifetime first officer. There were also unspoken issues related to his past performance that would have likely proved a barrier to both his selection and progression if selected. In both the conceptual models above, the captain would likely perceive the tone of this conversation as potentially threatening to his self-concept, particularly as it was taking place in the flight deck so he was firmly “in role”. The powerlessness implied by this perception of the “self” would be subject to *“comparison”* in Burke’s model which would result in a mismatch between the desired self and the actual self, resulting in psychological stress that would either result in a change in behaviour or a change in the way the situation is perceived. In the event, it appears that the Buffalo captain chose to re perceive his potential revised status in a positive light but with a caveat:

“...may not be a bad thing as long as I would be able to progress”... (Ibid., p. 254)

He appears to have been saying that he was only interested if progression was part of the deal. The factors outlined above made it very unlikely that such progression would be possible, thus providing a potential moral rationale for not accepting such a job whilst at the same time reasserting that he retained power in the choice of staying or going. No mention whatsoever was made about the loss of status involved in being a permanent first officer, as previously stated, this is not usually discussed. Overall, the topic of career progression carries considerable potential to challenge the captain’s self-concept which is likely to include the notion of being powerful in the work environment. If a speaker admitted that the increase in salary that accompanied such a job was needed, it would advertise that their future success was determined by someone else, in this case the airline. Although this is usually the case, if being powerful is an important part of one's self-concept, advertising this powerless position would be psychologically uncomfortable.

"I don't have to make two hundred thousand dollars a year" (Ibid., p. 255)

Burke's model proposes that an output to the environment that restores one's role identity is likely. The general tone of the exchange suggested that the speaker had considered such a move but for rational reasons he was not interested. As was demonstrated earlier, "feigning of disinterest" is sometimes used as a tactic used to emphasise that whatever someone is offering they cannot influence your decisions; for this reason the type of verbal behaviour outlined here should not be seen as deceitful but as a subconscious response to the stress that results when powerful people are reminded of their powerlessness. Both these comments emphasise to his addressee that he is not powerless, in fact the environment is almost exactly as he would have chosen. He is not influenced by the prospect of a high salary because money is not an issue for him. In addition to the rational explanation for his actions there is a moral one, because he is not a greedy person. These tactics also serve a self-esteem maintenance function.

Transcripts of the Buffalo and Kirksville accidents indicate that some pilots are quick to perceive challenges to their authority even when they are not intended to be so. Where a speaker held legitimate power over the person perceived as a threat their identity (such as a subordinate crew member) the exchange tended to be short whereas if the threat originated outside the hierarchical structure of flight operations, (such as from a manager), conversations tended to be more detailed and strategic in nature. Feigning of disinterest was a very recurrent verbal phenomenon in flight deck conversations and usually referred to not needing the incumbent job because another one was waiting in the wings, which is rarely the case. In the conversation above, about changing jobs and potentially becoming a first officer again, the captain was able to reassert his powerful position in the space of a few conversational turns, probably because of the hierarchical structure of the flight deck which clearly placed him in a superior position in the interaction. Differences in perceived power appear to influence the length and complexity of conversations. Powerful speakers appeared to achieve a congruent role identity very quickly as indicated by this description of an interaction between the Buffalo accident captain and a cabin attendant who had asked for clarification about a safety matter which he apparently viewed as a challenge to his authority:

"I just cut her off" (Ibid., p. 247)

Notably one of the longest conversations came from the Buffalo first officer and exceeded six minutes, describing an interaction with an airline administrator relating to her vacation which she was unable to resolve:

"I've left her voicemails she won't call me back. I've sent her emails she won't call me back… she won't change my vacation… I think I've got like two more days before I'm within the forty five days and they can't change it… and I know she's going to screw me over and I'm going to be so freaking mad if they make me take my vacation in March" (Ibid., p. 217)

According to the survey results this rant would likely be enacted for the purpose of self-promotion or to intimidate the listener. In this case there was an undertone of moral worthiness in the extended extract emphasising how reasonable the requests were and how unreasonable the response from the airline was. In fact, examples of ranting like this one are very uncommon on the flight deck but where they do occur they usually contain privileged content that the speaker would not wish to express in public. Referring back to this study's definition of self-promotion, it is conceivable that by ranting in such a forthright fashion she was attempting to recast herself as autonomous and powerful whilst recounting a narrative that posed a strong challenge to that identity. It is also relevant that she was firmly situated in her professional role identity with its implied power, which may have made the reestablishment of autonomy more important. Being a homeostatic process, the feedback loop proposed by Burke above would tend to drive a conversation such as this as long as social stress persisted. In support of this contention, the conversation above was only concluded after it was suggested by the captain that the speaker spoke to someone whose power probably trumped the person causing the identity challenge. Although this may sound like one-upmanship it is a realistic example of how conversation can be used as a vehicle for the homeostatic process of regaining power to maintain identity congruence. This example raises the question whether organisations have a responsibility to minimise the social stress experienced by employees involved in safety critical jobs. Research relating to high reliability organisations (HROs) including airline operations is clear on the subject; safe organisations locate the responsibility for error within the organisation rather than with the individual (Weick, 1987, Weick and Roberts, 1993). If it can be shown that relations with the organisation are responsible for frequent conversations on the flight deck, then according to the feedback loop proposed above, the work context needs to provide a more congruent self-identity for the pilots.

7.1.12 THE ROLE OF COGNITIVE DISSONANCE IN FLIGHT DECK CONVERSATION

Based upon the few transcripts examined in this study it appears that cognitive dissonance (the conflict between what an individual knows is right and what circumstances dictate they actually do) is an issue for flight crews. For instance, the Buffalo first officer acknowledged that she should probably have called in sick but for a number of reasons she flew anyway.

"I'm ready to be in the hotel room" (NTSB, 2010a, p. 196)

The transcript indicates that financial, professional and domestic pressures are likely to have influenced her decision to go to work.

"…two hundred bucks to a first officer is a lot of money…" (Ibid., p. 214)

Festinger (1957) proposed that individuals under this kind of conflict experience tension which they are motivated to reduce. The choices according to Festinger are clear; individuals reduce dissonance by "self-deception" or by reducing the aspects of their behaviour oriented towards "self-interest". Where an individual feels there is no more scope to reduce their self-interest such as when they already earn a low salary or experience poor terms of employment, they are likely to embark upon the type of self-deception Festinger described in order to justify their actions. Thus a complex conversation explaining the rationale for being at work when it appears one is unwell may well have its foundation in self-deception along the lines that the behaviour is acceptable because one has been pushed into it. Given that a human being who behaves in this way is just behaving the way human beings have been observed to behave for at least five decades it is surprising that organisations and regulators claim to be at a loss to explain such behaviour. The previous example was a junior first officer occupying a powerless position in her relationship with the organisation; as pilots progress they gradually come to occupy a more powerful position but can still experience stress when they are affected by matters outside their control. The transcripts describe how pilots took pre-emptive actions to wrest control back. Such discourse was indicative of a need to stay one step ahead of the airline and conveyed the message that whatever the organisation intended to do, the speaker was smart and powerful enough to prevent it.

The extract below is from the first officer of the St Louis accident aircraft:

"I left before they announced the airplane was going to come out;
I jumped ship real quick…" (NTSB, 2009, p. 92)

Another way that pilots appeared to attempt to restore their power in the relationship with their employer was to downplay their reliance upon their current job for their future success. The Buffalo first officer hinted that she had ambitions beyond her current job:

"I've got very very good connections at Alaska" (NTSB, 2010a, p. 251)

The transcripts included direct claims that a job was turned down and more indirect suggestions that the speaker was in control of whether they took a promotion or conversion to a particular type of aircraft, which is rarely the case. In the extract below, the captain describes how he turned down a job flying a jet:

"... I turned down the job because at that time they weren't they weren't paying anything for training". (Ibid., p. 204)

And how the choice of aircraft he flew was his for the asking:

"They gave me the choice of going on the 1900 or the Saab" (Ibid., p. 205)

The first officer also appeared to have the upper hand in terms of when she would be promoted:

"Yeah I don't know what to do about the upgrade. I'm not entirely in like a big rush to upgrade" (Ibid., p. 250)

First officers appeared to occupy a particularly powerless position in the airlines with talk dominated by disruptive base moves and the intention to move on to better things. Where pilots spoke of moving to other airlines there were also carefully constructed reasons why they had decided not to go. The following extract was from the Lexington flight crew talking about moving to the United Arab Emirates:

"They fly you if they can up to a hundred hours ... the apartments don't allow any animals and I have four dogs and I'm not about to give up... if I fly overseas, I wanna start and finish here in the States". (NTSB, 2007a, p. 129)

Although these might seem fruitless and misleading conversations they perform the function of illustrating to anyone listening that the speaker could go if *they* chose to do so. This assertion invokes the connotation that the speaker is competent enough to walk into another better job with ease and on their terms, which is rarely a realistic claim. Locus of control also provides a potential explanation for talk related to high wealth and valuable possessions which imply wealth as was evident in the Buffalo accident transcript:

"I don't have to make two hundred thousand dollars a year...
I can certainly be comfortable on a hundred thousand"... (NTSB, 2010a, p. 255)

The Charleston flight crew conducted a detailed conversation about expensive cars before their accident:

"...it's a 2004 fiftieth anniversary Corvette Convertible…"

…her dad drove us in his own Rolls Royce…

...the barn was filled with Corvettes, Jaguars… the Rolls was in there….

(NTSB, 2010c)

The ability to decide just how much control an individual allows one's employer to exert over their life is certain to be influenced by the ability to support oneself independently of employment. The survey respondents were clear that when they heard this type of conversation it was identified as self-promotion. However, it is important to emphasise that such conversations are probably not primarily intended to be boastful or to deceive the audience; rather they perform the essential function of self-esteem maintenance by reinforcing the self-evaluation that one is self-governing and not unduly affected by outside influences beyond one's control. The Buffalo accident captain emphasised that he had already had a successful career:

"It's like it's a second career for me basically…because I was able to take that package"

(NTSB, 2010a, p. 254)

It is important to emphasise that the veracity of claims of wealth, which are usually difficult to substantiate, are of less importance than the face work performed by appearing to oneself and others to control one's own destiny. Needless to say, cultural differences in locus of control exist (See Dyal,1983 for a review) but even individualist societies such as the USA have seen a tendency over the last two decades towards a more external locus of control (Twenge et al., 2004), meaning people feel more constrained by outside influences than they did in the past. This incongruence between an identity that relies upon being in control and the reality where increasingly more aspects of their operational decision making are controlled elsewhere is likely to be a continuing source of discourse on the flight deck.

7.1.13. SELF-PROMOTION ON THE FLIGHT DECK

An important observation about self-promotion on the flight deck is that it rarely co exists with any other explanation, indicating firstly that it is easily detected and secondly that its objectives are likely to be transparent to the audience. A further observation is that all the behaviours participants identified as self-promotion either directly or indirectly carry connotations of competence. Whether it is the ability to achieve promotion quickly, express a forthright opinion, acquire wealth or possessions or simply to put the interests of others first, competence would seem to be connoted. IM theory assumes that a basic human motive, both inside or outside organizations, is to be seen by others in a favourable manner and to avoid being viewed negatively (Goffman, 1959). Self-promotion includes exaggerating or highlighting one's accomplishments and abilities in order to be viewed as competent (Rosenfeld, et al., 1995) and is common, especially when involving influential audiences or circumstances and when the self-promotional claims are unlikely to be challenged or discredited (Ibid., p. 51). Pilots also need to establish role congruence; for instance the connotations of responsibility and stability attached to family life represent an effective way of conveying a variety of very influential impressions in a very short time, which may explain why such conversations are so common in the transcripts. Excesses of self-promotion are likely to be mitigated by the modesty norm, which dictates that people are perceived as more likeable when they slightly underplay their accomplishments (Schlenker & Leary, 1982). Arguably more important than the need to appear competent is the requirement to avoid looking incompetent, particularly to the few who may believe they fit that description. Speakers who feel it necessary to prepare an audience for substandard performance may adopt a process of “self-handicapping” where reference is made in advance to an external factor that provides a plausible explanation for their future performance. Transcript examples are difficult to find, but the fragment of conversation below was presented by the 59 year old captain of the Chicago accident aircraft as a justification for his reluctance to try a new procedure.

“...it's the old guy’s fear of... I don't know if I'm comfortable using the autobrakes this situation. First time...you know...having not even seen them operate before”
(NTSB, 2007b, p. 141)

In the St Louis accident report, the captain’s comment regarding his impending retirement was interpreted by investigators as a marker of a casual attitude:

“I’m ambivalent right now. I got six months to go” (NTSB, 2009, p. 72)

Although this captain had no previous history of substandard performance, it is important to note that the professional history of an underperforming pilot is unlikely to be known to other FCMs; in such cases it is possible that the pilot concerned might employ “anticipatory impression management” tactics such as exaggerating their skills, downplaying their ability or experience limitations or intentionally avoiding topics that might reveal those limitations.

This was the Buffalo captain: (NTSB, 2010a, p. 198)
“I’d been in the airline industry for a while...I was in a management position”

And this was the Detroit first officer:

"I've flown three line checks with three different captains" (NTSB, 1991b, p. 118)
"I retired as a lieutenant Colonel" (Ibid., p. 122)

In addition to mentioning one's own achievements, there was also evidence in the transcripts of friends and contacts in high places. Mentioning, even indirectly, that one was well connected was clearly recognised as SP but also had the potential to intimidate the listener. Both of the pilots of the Buffalo accident aircraft alluded to influential contacts in other companies, which implied that they would enjoy preferential status if they applied for a job.

"I even had an interview with Pinnacle to go fly the Regional Jets because they had a preferential interview process" (NTSB, 2010a, p. 204)
"I've got very very good connections at Alaska Airlines" (Ibid., p. 251)

The idea that an individual can self-promote by association with someone else may seem counterintuitive, but Manis, Cornell and Moore (1974) have provided experimental evidence that human beings tend to look similarly on things that are connected even in relatively trivial ways. Such research findings suggest that listeners sometimes conclude that if an individual appears to be closely associated with others who wield influence they might be of a *type* that share other desirable skills and attributes. For this reason it is not unusual for speakers to drop a hint implying that they are well connected without the need to risk explicitly claiming such a connection. There were no clear instances of an influential affiliation being mentioned as a means of intimidating a listener but the survey results indicate that at least some of the respondents could envisage such a situation.

"... I was in a management position... well I was temporarily in a management position". (NTSB, 2010a, p. 198)

The extract above from the Buffalo accident captain implies that the speaker possesses the skills and attributes of an airline manager without actually saying so. In this case not only had he been temporarily involved with the management of a relatively small airline but he mentioned that it had merged with a much more influential airline, which may have given the impression that he had been involved with the management of that company as well:

"I worked for the original Piedmont Airlines merged with US Airways" (Ibid., p. 197)

Clearly this vague type of discourse leaves open the possibility that a hearer might attach attributes associated with others who have reached high office in the airlines to the speaker. This type of *basking in reflected glory* (referred to as BIRGing by Cialdini et al., 1976) is also found where a speaker emphasises the positivity of something with which they are known to be associated; this study found multiple examples of crews extolling the virtues of having fun on the flight deck, which they appeared to believe they embodied in their operation. This was evident in the Kirksville accident transcript:

"Gotta have fun"

"That's truth man... gotta have fun" (NTSB, 2006a, p. 68)

And at Buffalo:

"Guys that have fun and enjoy their jobs are so much more pleasant to work with" …

(NTSB, 2010a, p. 265)

The converse situation to basking is known as *blasting* and involves deriding those whose values one does not wish to be associated with. Transcripts from Kirksville and Lexington contained examples that could be interpreted as *blasting* with a recurrent theme of referring to other pilots being "*uptight, taking themselves too seriously"* and needing *to "lighten up".* (NTSB, 2006a, p. 68)

"Yeah, but you gotta deal with a lot of Brits and Australians".
"You know it some of these Brits are a little up tight". (NTSB, 2007a, p. 131)

Two examples in the Kirksville transcript conveyed sufficient force to be considered a rant and in both cases there was an element of blasting involved.

"Too many of these [#] take themselves way too serious in this job"
"I hate it, I've flown with them and it sucks…a month of [#] agony" (NTSB, 2006a, p. 68)

7.1.14 INGRATIATION ON THE FLIGHT DECK

Tedeschi and Melburg (1984) provide a definition of ingratiation that is reflected in the airline context, defining the concept as "a set of assertive tactics which have the purpose of gaining the approbation of an audience that controls significant rewards for the actor". Much of the literature relating to ingratiation in wider organisational settings is about getting ahead whereas in the flight deck it seems to be more about getting along. Kelley (1973) notes that initial impressions can be difficult to dislodge even in the face of contradictory new evidence so it is important for crews to appear to be likeable as soon as possible. Six primary ingratiatory strategies have been identified in other organisational settings: *attitudinal conformity,* *behavioural conformity, court and counsel, favour rendering, other enhancement, and self presentation* (Strutton, Pelton, and Tanner, 1996).

ATTITUDINAL CONFORMITY

Attitudinal conformity occurs when an actor expresses opinions or attitudes that closely conform to those of a target individual. In the airline context this can entail agreeing with something that, whilst not wholly in agreement with, one holds no strong objection to. In the extract below from the Buffalo flight crew, the captain expresses attitudinal conformity with behaviour that he would have known was an infringement of the rules:

First officer*: ...”if I felt like this when I was at home there’s no way I would have come all the way out here…but now that I’m out here…”*

Captain: *“...you might as well…”* (NTSB, 2010a, p. 196)

Depending upon the force with which a target appears to hold a particular view, a speaker may choose to exaggerate their support for their target’s view. One can also signal agreement by the use of *imitation:* in at least two of the transcripts (Chicago and Kirksville) there was some evidence of imitation of a colleague’s verbal behaviour.

First officer: *“The weather outside is frightful (in a sing voice)”*

Captain: *“The weather outside is rosey”* (NTSB, 2007b, p. 122)

Captain: *“Gotta have fun.”* First officer: *“That’s the truth man; gotta have fun”*

(NTSB, 2006a, p. 68)

This type of imitation is likely to invoke the similarity attraction paradigm, which suggests that perceived similarity among dyadic "partners" increases their mutual attractiveness to one another (Byrne, 1971).

COURT AND COUNSEL

"Court and Counsel" describes the tactic of asking an influential target for their opinion or advice on a subject, thereby emphasising how much their opinion is valued. Enquiring of a manager what they thought of your interview technique represents quite a blunt instrument in terms of *court and counsel* but there was a description of such an event, where the Buffalo accident captain described a discussion he had with his interviewer after interviewing for his current job:

"I interviewed with …and I asked him after the interview…I said you know that was an honest answer; I'd be more challenged in the Saab. He said no man that was a perfect answer" (NTSB, 2010a, p. 206)

A more identifiable manifestation of this on the flight deck would be the act of resisting the temptation to explain that one already knows some technical detail or procedure that is being carefully explained. In the example below, the same captain is explaining how to fill in the technical log, which the first officer, who had been qualified on the type for eleven months, probably knew anyway.

Captain: *"you don't write it in until you land there"*

First officer: *"right that makes sense"* (Ibid., p. 238)

FAVOUR-RENDERING

Rendering a favour to a colleague by verbal means in the flight deck context was uncommon in the transcripts. However, Strutton & Pelton (1998) provide a sense of the abstract nature of favour rendering possible in organisational settings by suggesting that even the type of feigning of interest shown above represents a favour rendered. In this case the favour may be as abstract as avoiding the speaker's embarrassment by not mentioning that he is teaching you something you already know. Favour-rendering involves the actor's conveyance of some kind act or special consideration to a target; both sharing a confidence and offering sympathy or empathy to a colleague fit into this description, as do *face-saving* or *enhancing* measures. In the first example below, the Buffalo accident captain renders the favour of sympathy, whilst the second represents the favour of sharing a confidence.

"I feel…bad for you as far as feeling #". (Ibid., p. 196)

"I was gonna tell you something. I didn't want to really say it…uh in front of the ramp guys" (Ibid., p. 194)

All forms of favour-rendering have potential to be motivated by the reciprocity norm; the expectation that an addressee might behave in a similar fashion to you in the future. The storing of favours may be particularly useful for the underperforming pilot. Applebaum and Hughes (1998) comment that individuals with low productivity but high ingratiation skills can achieve career success despite limitations in the way they do their job. This however, does not explain why so much indirect favour rendering from pilots who were considered competent was heard in the transcripts. Both captains and first officers agreed to infringe rules, gloss over errors, and feign agreement and interest. The fragment below was the Lexington captain's response to his first officer asking for an already complete checklist, which would probably have been a source of mild embarrassment for the first officer:

"Hey man, we already did that one" (NTSB, 2007a, p. 143)

Research with interdisciplinary surgical teams (Edmondson, 2003) indicated that under reacting to an error in the way indicated above, was an effective strategy for leaders to mitigate the effects of power differences within the team. Furthermore effective team leaders sometimes made a point of acting upon others' inputs thereby emphasising the importance of the team. Such *transformational leadership* was not always evident from the transcripts, some of the exchanges in these examples of SFP being more akin to the *transactional leadership* described by Burns (1978) which entail an exchange between leader and follower, where followers receive certain valued outcomes on condition that they act according to their leader's wishes. The pilot who disagrees with a colleague over an operational matter has a number of factors at stake. Firstly the loss of face implied by having an opinion dismissed is likely to invoke the need to remedy the situation in the interests of self-image maintenance. In such cases the feigning of either agreement or ambivalence is predictable, as was the case in this exchange between the two FCMs who crashed on takeoff at Washington in 1982.

First officer: "do you want me to do anything special for this or just go for it"
Captain: "unless you got anything special you'd like to do"... (NTSB, 1982, pp. 126 127)

In this case the first officer did have a plan regarding how he would fly the takeoff but he only voiced it once he had sounded out his captain's opinion, thereby avoiding the possibility that his suggestion would be rejected. The captain's vagueness was highly inappropriate given the poor weather conditions that existed. A second explanation evident in the transcripts is an apparent reluctance of FCMs to be viewed as being excessively rigid in their outlook in case they attract negative evaluations from colleagues; this phenomenon was evident in the Kirksville and Lexington transcripts. In fact what is being described is a transaction or deal between the two pilots in which both have a stake. The fragment below was the Chicago accident first officer's response to his captain's reluctance to comply with a prescribed procedure:

"…I would be cool with whatever your decision is" (NTSB, 2007b, p. 141)

In addition to the "valued outcomes" for the individual that Burns (1978) believed characterised such transactions, it is also conceivable that such behaviour is enacted for the benefit of the organisation, particularly when organisational and personal needs coincide. The type of *helping behaviour* above has been identified as an important form of *citizenship behaviour* by virtually everyone who has worked in this area (cf. Borman & Motowidlo, 1993, 1997; George & Brief, 1992; George & Jones, 1997; Graham, 1989; Organ, 1988, 1990a, 1990b; Smith, Organ, & Near, 1983; Van Scotter & Motowidlo, 1996; Williams & Anderson, 1991). The notion of voluntarily helping a colleague thereby avoiding work-related problems is intuitively understandable and has been conceptualised by Organ (1990a) as the construct *peacemaking* in his model of Organisational Citizenship Behaviour. Organ's *peacemaking* construct emphasised the importance of resolving or mitigating unconstructive interpersonal conflicts in the interest of the organisation's needs. This begins to explain why so much of the cooperative conversation heard in the transcripts has an undercurrent of non-compliance with organisational norms. The first officer at Chicago cited above, who said he would agree with "*whatever his captain decided"* was not in a position to make that decision at the time of speaking because he could not predict what those decisions might be. In fact the captain's decision was found by the investigation to have infringed a rule in relation to the amount of tailwind accepted for the accident landing (NTSB, 2007b, p. 67), so it is clear that such a blanket statement of intent to agree was not appropriate. However, the first officer had nothing to gain personally by adopting that stance so it is conceivable that his behaviour, although errant, was enacted in the organisation's interest. An explanation for this type of non-compliance is found in the conflict between Organ's *peacemaking* within the flight deck and complying with organisational norms. In such cases there may be considerable pressure to conform to the needs of the immediate group because if team performance is eroded then the interests of the organisation are likely to suffer (Podsakoff et al., 1997). In the flight deck context, the successful outcome of a flight is dependent on the combined performance of the flight crew, thus it could be argued that when one is likely to be judged upon the team's effort rather than individually, there is an incentive to help one's direct colleagues to achieve successful outcomes regardless of their methods. Thus in some cases complying with group norms rather than organisational norms could be seen as beneficial to the organisation. In wider organisational settings the incidence of ingratiatory behaviour is higher in the upper levels of management (Allen et al., 1979, p. 80); furthermore, in such contexts most ingratiatory behaviour is observed from subordinate to superior. Thus in most organisational settings ingratiation tends to be used more as an upward influence process than as a downward influence processes. The flight deck context emerged as qualitatively different insofar as although the rest of the crewmembers are subordinate to the captain, she/he has very little scope to return any material favour such as career advancement, which suggests that there must be other motivations at work. The transcripts and expert opinion expressed by Deborah Hersman in the Lexington accident report suggest that for some flight crews, behaviours such as infringing the sterile cockpit rule might represent the norms of the group (NTSB, 2007a, p. 113). The ingratiatory effect of ignoring that a colleague is breaking a rule is intuitively understandable but it is also conceivable that such rule breaking is an example of prosocial behaviour. A well-documented characteristic of prosocial behaviour is that it is strongly influenced by the models of behaviour that represent the target individual or group. This means that individuals may feel compelled to behave in line with the group norms out of a belief that they would not be being a good team member if they refused to do so. Although it is impossible to generalise from the small sample of transcripts used for this research, there is an indication that for some crews, a model of sociability expressed via conversation is a dominant prosocial behaviour in the flight deck context. This is not surprising given the considerable evidence linking *sociability* to concepts such as transformational leadership (Bass, 1988) and charismatic leadership (House, 1977) and the negative connotations attached to being unsociable. Krebs (1970) reviewed more than two dozen modelling studies and concluded that so long as a given behaviour appears salient, and expectations and consequences are clear, group members are likely to consider participation in such behaviour as a prosocial act. Furthermore, at some point a pattern of social exchange is initiated (Dansereau, Graen, & Haga, 1975) which becomes subject to broader norms of reciprocity (Gouldner, 1960). Put simply this means that if the behaviour appears reasonable it is likely to be adopted, and once that has happened, group members will feel uncomfortable not complying. Existing research (Barling, Weber & Kelloway, 1996) indicates that the level of commitment a leader demonstrates to an organisational norm influences the likelihood of followers behaving similarly. The transcripts support the notion that if a captain appears to support a group norm such as sterile cockpit rule infringement there is a strong possibility that a subordinate might behave in a similar way. If the group norm conflicts with the organisational norms the subordinate is faced with a problem of cognitive dissonance where self-concept may be threatened by the choice between breaking a rule or appearing to be anti-social, neither of which are likely to represent their *desired-self*. It was proposed earlier that the maintenance of self-concept may be under control of the autonomic nervous system, in which case the reduction of psychological discomfort might provide the subconscious motivation to view a rule infringement such as conducting a non-pertinent conversation as desirable rather than aberrant behaviour. Instances of both upward and downward ingratiation were evident in the transcripts, and whilst the research outlined above mainly addresses upward ingratiation very little has been written about ingratiation from superior to subordinate. In addition to the simple rational explanation that it costs nothing to offer a compliment and it may improve crew cohesion there may be organisational objectives that are served by downward ingratiation. The transcripts indicate that subordinates often view the captain as a link to the wider organisation, which suggests that as a superior they need to be sensitive to both group and organisational needs. Sympathising or empathising with a colleague could well qualify as an OCB if it is enacted with the intention of defusing a situation that was affecting their work. In one transcript extract involving a co-pilot who was in dispute with the organisation regarding her leave allocation (NTSB, 2010a, pp. 217-222) the captain commented that he understood her problem, suggested who to contact but stopped short of agreeing with the organisational shortcomings expressed. It is conceivable that faced with a co-pilot who appeared stressed the captain may have considered it a higher priority to express agreement than to voice a potentially conflicting view. This is an example of how ingratiation can be used as an OCB by appearing to agree even if in reality one takes an opposing position. Research by Bavelas (1985) has found that speakers who are faced with a situation like the one above, where to fully support the criticism of the organisation would probably not conform to their professional responsibilities or actual opinion, whereas to disagree would alienate their colleague, are in a bind known as avoidance/avoidance conflict (AAC). Bavelas observed that in such situations speakers use a variety of strategies to avoid revealing their true opinion, of which ingratiation may be one. One of the most convincing explanations for downward favour rendering relates to the mutual reliance required by the flight deck role. Specifically, task groups characterized by reciprocal interdependence are expected to display more citizenship behaviour than groups in which independence or sequential dependence is the rule. According to Thompson (1967: 54-55) reciprocal interdependence requires frequent instances of spontaneous mutual adjustment in order to effect coordination of the type evident at Lexington:

"...run the checklist at your leisure..."

"...keep me out of trouble. I'll do the same for you" (NTSB, 2007a: p. 139)

One favour that captains regularly offer to first officers is the opportunity to choose which leg of a trip they fly. This very common practice involving flying alternating legs of a trip was evident in the Lexington transcript (Ibid., p. 136). This type of favour, although seemingly unremarkable, carries some symbolic relevance inasmuch as it signifies that the captain trusts the first officer to make a decision that he/she would normally make. Gillespie (2003) has identified the type of "reliance" described above as a salient form of trusting behaviour in working relationships. When superiors share control they demonstrate significant trust in, and respect for, their subordinates. Subordinates value being involved in decision making because it affirms their standing and worth in the organisation. Despite these positive features of delegating control, the transcripts provided evidence that sometimes such offers are refused, and this has also been observed in naturalistic observations conducted for this study. An important feature of such offers is that they only operate in a downward direction from captain to first officer and this is true of most operational favours that are conceivable on the flight deck. Whilst favours that cannot be reciprocated have been found to be a particularly effective ingratiatory tactic, the downside is that they emphasise the unequal power relationship omnipresent on the flight deck. This is the type of offer that has potential to pose a threat to the self-esteem of the subordinate, particularly if it is a persistent feature of one's subordinate role. This phenomenon may explain the tendency for first officers to often refuse to make the decision, returning it to the captain. Although probably subconscious, this could be interpreted as an indication of the pervasiveness of self-esteem maintenance processes. The extract below sees the captain offering the first officer the choice of which leg to fly. The first officer's dismissive refusal to choose represents a considerable contrast to the way in which offers of kindness are handled in everyday conversation. This may be a subconscious attempt to regain some power in the interaction; however, the captain reasserts his power in the exchange by insisting that he is not intending to decide. Ambivalence, such as that expressed by the first officer below, can be a useful device in the hands of less powerful participants for dealing with those with power; but those with power may respond by enforcing explicitness (Fairclough, 1989) as was the case at Lexington:

Captain: *"did you bring it (the aircraft) in the other day or what's the sequence?"*

"...keep on with whatever you're doing

" First officer: *"it don't matter to me"*

Captain: *"Oh, I'm easy buddy"* (Ibid., p. 139)

Fairclough also notes that powerful participants in an interaction are often in a position to specify its content and purposes. He suggests that one way of exercising power in discourse is by placing constraints upon the contributions of less powerful participants. Although this was not evident in the transcripts, it is conceivable that a subordinate might subconsciously attempt to steer a conversation towards a topic where such power inequality is less likely to be manifest. Whilst Fairclough describes such controlling of conversation topics as a conscious process enacted to exercise power, in this context it may be used to minimise power inequality. There were several examples of captains either self-deprecating or emphasising the similarity between themselves and the first officer, as in this extract from Buffalo accident captain:

"But it would happen, the exact same thing with me as it would with you"
(NTSB, 2010a, p. 186)

For a captain, minimising power inequality in this way would seem to be motivated by altruism whereas for a first officer, steering a conversation away from topics that persistently emphasise their relative powerlessness might be a subconscious response to autonomic stress so induced. This introduces the possibility that a conversation relating to a more equal topic such as family life could be enacted for a range of reasons depending on who initiates it. Furthermore the motives may range from self-image maintenance to the exercise of organisational citizenship.

OTHER ENHANCEMENT

Other enhancement is really a technical term for flattery; the tactic of expressing laudatory appraisals of a target whilst diverting attention from any negative features. Where direct flattery did occur it was usually referring to a preference for colleagues who adopted a relaxed approach to the way they operated. There were two clear instances of praise being given in response to a conversation about helping a colleague; in both cases the conversation that prompted the flattery was unsolicited by the addressee. Although the transcripts contained very few instances of direct flattery there were many instances of flattery of a third party. It is not clear what purpose this serves except perhaps to indicate that one is the type of person who habitually says nice things about others and is therefore unlikely to say anything negative to others about the addressee. Less overt flattery was evident in imitation of the exact phrases used by a colleague and in some cases this appeared to support actions that would fall outside organisational norms but perhaps satisfy the social norms of the pilot group. The flight deck emerged as an environment where individuals who are sometimes only marginally acquainted share confidences or express intentions, some of which they would not wish to be made public. Although it may seem unusual for marginally acquainted individuals such as the FCMs in the Buffalo accident to share confidences or express forthright personal opinions, Granovetter (1973) provided a mathematical framework whereby individuals who share acquaintances despite not knowing one another, are likely to readily develop strong relationships. It was evident early in the conversation between the two marginally acquainted FCMs at Buffalo that whilst other members of the pilot community could be trusted with certain types of information, this would not necessarily be the case for outsiders such as ramp agents, cabin attendants or the wider organisation.

"I was gonna tell you something. I didn't want to really say it in front of the ramp guys" (NTSB, 2010a, p. 194)

The survey respondents were very clear that they viewed confidence sharing as a manifestation of normal friendliness first and ingratiation next. In fact, being sociable is an important feature of coalition building but it does seem likely that a by-product of such friendships is cliquishness that is effective at the level of the individual group (in this case the pilot community) but less so at an organisational level. This may represent the basis for an explanation of the seemingly widespread willingness to view rules like the sterile cockpit rule as amenable to interpretation at the level of the professional group rather than at the organisational level.

SELF-PRESENTATION

Self-presentation as an ingratiatory tactic refers to behaviour that emphasises characteristics that are known to be approved of by the target audience. Schlenker (1986, p. 23) has provided a potentially useful approach to understanding “others as an audience”. He uses the broader term “self-identification” to refer to the "process, means, or result of showing oneself to be a particular type of person, thereby specifying one's identity". Generally speaking, the motive to engage in self-presentation springs from the same motivational source as all behaviour, namely to maximize expected rewards and minimize expected punishments (Schlenker, 1980). Although Schlenker’s view ignores the possibility of altruistic behaviour there is likely to be some truth in his model of human motivation. An important determinant in the incidence of self-presentation is the value of the desired goal, and this is different for different individuals and contexts. A first officer nearing upgrade may have a stronger motivation than a new hire to self-present as competent and this motivation may be further enhanced if upgrades are scarce. Even though on routine flights first officers are not evaluated, the transcripts suggest that the maintenance of a competent professional image is important. Referring back to Goffman (1959) it is important to be seen in a positive light, and for a pilot this includes portrayal of competence. Where one’s self-image is under threat, the motivation to indulge in self-presentation is likely to be greater. As a result, people often try to make impressions that will elicit esteem enhancing reactions, particularly when they expect feedback from others (Schneider, 1969). At the heart of self-esteem is the discrepancy between one’s desired and current images. Individuals have a range of images that they regard as acceptable to project. When they believe that the impressions others have of them fall outside this range they become motivated to actively manage their impressions. Thus, it is predicted that a pilot with a self-esteem issue (such as a history of substandard performance) might be motivated to seize any opportunity to self-present as competent to an influential audience. If, as is expected, such a tactic elicits compliments or praise, that will serve to enhance self-esteem. Self-presentation allows individuals to maximize their reward cost ratio as they deal with others (Schlenker, 1980). The tangible reward for an underperforming pilot is the hope that one's current image might be steered in the direction of one's desired image because under-performance is a psychologically uncomfortable state. The potential cost is that the attempt is obvious to the audience, in which case one's image might be further damaged. In the aviation context there is an assumption of competence that tends to militate against routine aggressive self-presentation among pilots who meet accepted standards. This means that a pilot indulging in self-presentation risks being viewed with suspicion by colleagues because the desired identity of many pilots is one where their competence is evident from their actions rather than stories about their own qualities.

7.1.15 EXEMPLIFICATION ON THE FLIGHT DECK

Exemplification occurs when individuals go above and beyond what is necessary or expected in order to be perceived as committed or hardworking. Although survey respondents recognised the phenomenon of pilots who talk of rule stretching and acceptance of inconvenience in the interests of the organisation, where such talk occurred in the transcripts the beneficiaries tended to be other colleagues. There was also some evidence that pilots preferred to talk about situations in which they acted in line with group norms rather than organisation norms.

7.1.16 CREW COHESION ON THE FLIGHT DECK

The participants' responses indicated that *agreeing* was an important factor in conveying the sense that there was a common objective on the flight deck. Pilots back-pedalled in discussions and agreed with comments that they had previously appeared to disagree with. This type of responsiveness to other team members' contributions has been shown to have the effect of building consensus and a range of other features reflecting the social climate (Bales, 1976; Rogers & Farace, 1975). Research involving groups as diverse as gangs (Conquergood, 1994) and rural communities (Heath, 1983) indicate that the adoption of a common lexicon is a subtle linguistic device commonly used to promote cohesion within social groups. The lexicon of cohesion on the flight deck appeared to centre upon interest in, and support for the in-group represented by the immediate pilot community. There was also a recurrent unofficial lexicon associated with critique of out groups such as other pilots, airlines and support staff. Traditionally, cohesion research has emphasised the role of interpersonal attraction (See Lott and Lott, 1965) but recurrent features of the transcript conversations, such as the marked tendency towards intra-crew agreement (See Bennett, 2010) and criticism of out-groups of whom the speaker had no detailed knowledge, indicate that crew cohesion may be more multi-faceted in the flight deck context than in more general contexts. For instance, intra-crew disagreements were very quickly resolved in the transcripts whereas conversations relating to out groups such as managers were longer and more complex. More recent social-cohesion research has focused upon how individuals align what they say with the characteristic features of the social group for tactical reasons. Social identity theory (Tajfel and Turner 1986) introduced the idea that people categorise themselves as either individuals or group members depending on the context pertaining. An important aspect of categorising oneself as a social group member is the depersonalising effect this has. In such contexts the speaker speaks not as a unique individual but in terms of the social group's defining features or prototype. In-group prototypes tend to be positive whilst out-group prototypes tend to be negative (Dion, 2000, p 19.), an observation which was supported by the transcripts. The transcripts indicated that out-groups including managers, pilots from other bases and those not embodying the group identity were subject to derogatory comments whereas those who embodied the defining features of the in-group, such as being "relaxed" and "having fun" were discussed in positive terms during flight deck conversations. This orientation towards in-group sociability suggests that, in line with existing research (e.g. Fitzgibbons et al., 2004) the pilots in the transcripts were extraverts who enjoyed interacting with other members of their social group. According to Watson & Clark (2004) extraversion is associated with "positive affect", in other words, being upbeat about life, which in turn increases social cohesion. Another common strand in flight deck conversations was the expression of interest in a colleague's personal life, a type of person-oriented behaviour that has been associated with the enhancement of social cohesiveness (Tjosvold, 1984 and Stogdill, 1974). The current research indicated that expressing an interest in a colleague's personal life was interpreted as normal friendliness and cohesive behaviour, a finding that accords well with research such as Rozell & Gundersen (2003) whose research supports the notion that group cohesion can be influenced by demonstrating this type of emotional connection with an addressee. Given that pilots appear to be aware of the strategic value in terms of social cohesion of such talk, it is understandable that the content should be targeted at maximising its effectiveness. Social cohesion is achieved by emphasising similarities; however, the hierarchical structure of the flight deck means that any discussion of work related matters has potential to be influenced by the unequal power relations therein. This is more than just intuition; even in sociable conversations related to work, captains were more able to disagree or offer advice to a first officer than vice versa. Notably, in two separate transcripts, captains were heard talking about jobs that would have required that they fly as a first officer; in neither instance did the captain demonstrate much enthusiasm for the idea. This indicates that whilst the first officers in the transcripts tended to be dissatisfied with their lot, captains were less so. First officers had two persistent conversation topics; their command prospects and their attempts to progress to a major airline. For captains, the former issue was clearly irrelevant and the latter becomes less of an option as they get used to being in command. Nonetheless as this is a persistent topic it is conceivable that captains might choose to "self-present" as being similarly affected in the interests of minimising the perceived differences between the two colleagues. What is being proposed here is that captains not only strategically avoid discussing aspects of their professional situation that emphasise their relatively advantaged position but sometimes they actively de-emphasise that position. Philips, et al. (2009) theorised that members of demographically diverse work groups may strategically disclose personal information at work in order to manage the perceived differences in status associated with demographic categories. They focus upon group members' concerns over increasing the perception of social distance, and theorise that both low and high status group members might selectively disclose personal information in work settings to minimise status differences and increase group cohesion. However, they also acknowledge that the longer group members spend together the more they learn about one another and so it becomes more difficult to practice this strategy. Where selective disclosure is not possible it is conceivable that social distance between group members could be widened (Phillips et al., 2009, p. 724). Disclosure of personal information emerges as a tactic to be used judiciously, with the potential for differing outcomes depending on a range of factors such as the length of time two pilots have known one another and crucially, the sensitivity of the speaker. On any given day the members of a flight crew will vary along a continuum between quite similar to very dissimilar; in the Buffalo accident the captain was a 47 year old man and the first officer was a 24 year old woman. It is reasonable to speculate that these two pilots had little in common other than their chosen occupation. This study has discussed the implications for cohesion of excessive work related talk but where should the conversation go if two people have very little in common? The transcripts indicate that talking about family life is an effective way of disclosing important information in a timely fashion; the first officer above disclosed her city of residence, her marital status and her plans to buy property, all in the first significant sentence she contributed. In fact, marital status often emerges as a discussion point quite early in conversation and this probably has to do with the amount of information conveyed by that single fact. Theories of cognitive economy propose that human beings categorise concepts on the basis of what they already know about them. Being married implies that in many, but not all cases there may be some shared experience regarding children. The conversation can then spread out in many safe directions because the dominant model of what family life means is so clearly defined. The importance of establishing some common ground between colleagues cannot be overemphasised because it has been shown that introducing a topic in which there is no shared interest often falls flat (Stasser and Titus, 1985, 1987) and contributes neither positively nor negatively to cohesion. The incidence in the transcripts of talk that minimised power differences within the group was so prolific that it appeared to represent an essential component of the flight deck group prototype. It was also proposed earlier that the influence of a strong group prototype can result in speakers behaving in ways that embody the values of the social group but may be counter to their own norms of behaviour. If this proposition is accepted, it goes some way to explaining the hitherto unexplained reason for uncharacteristically unprofessional behaviour from pilots who had a good reputation. On the other hand, this portrayal of pilots is problematic given some of the personality features mentioned earlier, such as “internal locus of control”, which would seem to militate against such influences. The answer to this problem may lie in the strength of the salient features of the flight deck context which distinguish it from everyday life. For instance, pilots exercise a degree of autonomy when “in role” that is unusual for non-management grade employees. They also enjoy a high level of respect from the public that probably stems from a reliance on the pilots’ professional skills to secure their safety. They wear a uniform; they comply with a defined hierarchical structure and they identify with the organisation whenever they transmit on the radio or make a passenger announcement. Hogg and Hardie (1991) studied the group identity of members of a sports team and found that judgements about those team members were more closely linked to the characteristics of being a team member rather than their individual characteristics. The salience of the group identity is crucial in this process; where a group identity is strong enough to result in a noticeable change in the way a person acts or is viewed by observers it can justifiably be considered a highly salient identity. Naturalistic research (e.g. Hogg & Hardie, 1991: Hogg & Hains, 1996) indicates that in contexts where the group is highly salient, the most effective way for an individual group member to gain a favourable evaluation is to identify strongly with the group prototype. Although there were some recurrent characteristics of the flight deck group, such as friendliness and interest towards immediate colleagues and occasional cynicism and critique towards those outside the immediate group, it was also clear that individuals' professional standards were highly influential in modifying the group identity on any given flight. This means that in the face of a captain deciding that a flight will be conducted in a particular fashion it is likely to be difficult for a first officer to adopt an opposing position and still retain a cohesive working environment. The transcripts include several examples of first officers going along with unauthorised conversations seemingly because it fitted with the group prototype as modified by a particular captain. Although this represents a cognitive dissonance issue because it is likely that at least one participant would be falling short of their own standards, the depersonalising effect of behaving in line with the group identity would seem to facilitate such action. As long as group identity is complied with it will be possible for speakers to speak in ways they might not wish to in more public contexts. The extract below features the words of the captain who became a national hero after ditching an Airbus in the River Hudson. His communication skills were described as "excellent and professional" by investigators:

"I'm gonna just call this guy directly because I don't think this ops guy knows what the # he's doing" (NTSB, 2010b, p. 156)

In several transcripts there is at least one sideswipe at a group or individual outside the direct group but very restrained criticism of any transgressions within the group. Several common strands appear in such conversations, including a narrative suggesting that standards or efficiency outside the social group may not be as high as within the social group. There is also a persistent narrative strand related to the perceived inadequacy of management. The fragment below is part of a telephone conversation conducted by the captain of the Charleston accident immediately after the accident, commenting on the likelihood of being able to contact a manager by phone.

"I mean obviously neither of them are gonna answer their phone" (NTSB, 2010c, p. 12-30)

In summary, the transcripts suggest that safe topics such as family life are often used as a conversation starter enacted to find some common ground between speakers. Research from other contexts suggests that the strategic management of disclosure of personal information can reduce social distance and thereby improve group cohesion. The accident literature contains clear instances of pilots strategically withholding personal information. The avoidance of work related topics as a tactic to minimise unequal power relations offers a plausible explanation for the incidence of the seemingly mundane conversations in the transcripts. Unique features of the pilot group identity make it highly salient, which provides a motivation to speak in ways that reinforce that identity. The transcripts indicate that embodying the characteristics of being a pilot might outweigh the influence of being a part of the organisational group. This observation is based upon the ease with which pilots discuss their career independently of their current employer. This formulation of a cohesive group within the flight deck appears to be strengthened by the notion that those outside the inner circle of the pilot group are a legitimate target for criticism.

7.1.17 SELF-JUSTIFICATION ON THE FLIGHT DECK

Self-justification is a tactic to control the state of psychological tension that occurs whenever a person holds two inconsistent cognitions, such as the belief that one can still be considered highly professional despite infringing a rule. This situation induces a state of cognitive dissonance which is likely to be harmful to an individual's self-image if not checked. Cognitive dissonance reduction is viewed by many experts as an adaptive strategy, or a primary cognitive mechanism which may or may not be engaged in consciously by the individual. The transcripts suggest that there are two broad types of justifications, those that are pre-rehearsed and those that are enacted in reaction to a threat to self-concept. It is important to note that self-justifications appear to perform two distinct functions, maintaining one's identity to the outside world and matching up to one's own self-concept. The former is likely to be highly influenced by a schema related to how pilots behave at work, and this will define the types of justifications that pilots use in a range of situations. The latter is constrained by an individual's self-concept such that regardless of what the outside world thinks of one's behavior, if it fails to meet one's own self-concept a range of adaptive processes are likely to be invoked. In practice what appears to occur in such cases is that the individual subconsciously justifies the infringement in the interests of confirming that they meet the standards that define their self-concept. None of the transcripts provided any hint that the pilots were uncomfortable breaking the sterile cockpit rule, an observation, which supports the view that these pilots had incorporated this type of behaviour into their model of how a professional pilot should behave. This is an important observation because it indicates that these pilots did not view this type of infringement as a challenge to their self-concept otherwise they would have been motivated to stop. Flight deck conversations represent a challenge to self-image due to several competing requirements, including the need to communicate effectively, the need to comply with the sterile cockpit rule and the need to work as a team member. The founder of cognitive dissonance theory, Leon Festinger describes cognitive dissonance reduction as a basic process in human beings, which implies that like most motivations it occurs without the conscious effort of the individual involved. This means pilots will be motivated to embrace ideas that justify their conversations on the flight deck, and these are quite readily found. Potential justifications could include the fact that pilots are encouraged to make passenger announcements and respond to ACARS messages as they prepare to depart. These two phenomena featured in serious incidents at Seattle (NTSB, 2008a) and Hong Kong (Civil Aviation Department Hong Kong, 2011) respectively. Also most pilots understand that although the sterile cockpit rule usually only applies on the ground if the aircraft is moving, it is equally possible to miss a crucial clearance or omit an essential action due to distraction whilst the aircraft is stationary, as was the case at Dallas (NTSB, 1989). These and other practices provide plenty of scope for an individual to justify the occasional conversation during a sterile cockpit period. It should be emphasized that these are not necessarily examples of flagrant rule breaking; they represent behaviour motivated by the human need to meet the standards of one's own self-image. In time the process of cognitive dissonance reduction is likely to find ways to justify the behaviour and then the motivation to change is gone. Until cognitive dissonance is controlled, such issues are moral problems concerned with weighing what one believes is right against what is dictated by the rules. The transcripts indicate that the tension between acceptable moral behaviour and professional rules provides much scope for cognitive dissonance issues. In the Buffalo accident transcript the captain is heard consenting to fly with a first officer who was clearly unwell (NTSB, 2010a, p. 196). In this case his responsibility to ensure that all his crew members were fit to fly might have conflicted with his perceived moral obligation to avoid getting a colleague into trouble by refusing to fly with her. In cases like this where all the options challenge an aspect of one's self-concept, speakers sometimes downplay the importance of their actions. In this example the captain emphasized the trivial nature of the first officer's illness by suggesting it could be remedied with orange juice (Ibid., p. 196). The only justification from the first officer was that she was "pretty tough", (Ibid., p. 196) which represented a denial of the true impact of her behaviour. Both denial and trivialization are well documented justification tactics. Retrospective judgments in the literature, of this FCM's actions indicate that neither of these justifications would have gained approval from any of the stakeholders in aviation safety so these justifications were almost certainly not primarily concerned with how her peers might view her actions. The obvious alternative explanation is that these self-justifications were a way of conceptualizing the behaviour to make it fit with her self-concepts. Cognitive dissonance reduction usually involves justification that reinforces a sense of an ethical or moral justification for the rule infringement. This FCM's justification was mostly that by reporting for duty she would be "on the company's buck" (Ibid., p. 196), meaning that the company would be financially responsible for her welfare. This is an exceptional justification inasmuch as it makes no pretence of an ethical or moral justification for the behaviour. This important and unusual observation suggests that no cognitive dissonance existed, which means that although the speaker knew it was wrong, the behaviour caused no psychological discomfort. Given that any pilot would be aware that flying when unwell was breaking a rule, it is reasonable to suggest that a pilot breaking such a rule without any serious attempt to justify it, was acting in accordance with their self-concept. This in turn prompts an examination of the factors that might contribute to a pilot's self-concept adapting in such a way as to justify such behaviour. Research into work motivation (See Leonard et al., 1999 for a review of traditional work-motivation theories) indicates that where inequity exists between inputs and rewards, cognitive dissonance will result. This means that an employee who perceives that they are undervalued may be motivated to lower their standards to a level where they feel they are achieving equity. Whether justified or not, this first officer gave several indications that she thought she was undervalued by the organization (NTSB, 2010a, pp. 217-220). Where a mismatch exists between what seems to be right and what actually occurs, a cognitive dissonance issue is likely. This is an issue that airline managements should not turn their back on. Any worker who feels there is inequity between what they are expected to give in terms of professionalism and how they are treated is likely to be subject to unconscious motivations that result in a reduction in the quality of their self-concept which could result in a decline in their work performance. Arguably, the most potent threat to a pilot's self-concept is the realisation that he or she is on the borderline in terms of the competence required by their role. Although mentioning that a job has been turned down is mainly associated with self-promotion it plays an important role for the pilot who cannot change jobs because it is just too risky. Any pilot who has failed multiple check rides (as was the case with the Buffalo captain) will not only have a documented history but will very likely experience similar difficulties in a new job. However, for many pilots there is a well-defined career structure that often involves progressively better jobs for the first few years of one's career. If it is clear that this is not happening to an individual, there is potential for this to become a matter for discussion. One of the Lexington pilots spoke of the need to blend in in the airlines (NTSB, 2007a, p. 131) and this includes progressing at a normal rate. The first officer at Buffalo discussed how her peers seemed to be in a hurry to be upgraded whereas she was happy to wait to gain more experience (NTSB, 2010a, p. 251). This strategy, known as "disassociation" involves distancing oneself from any possible negative outcomes by asserting in this case that, for quite honourable reasons one is not seeking an upgrade. This can also further enhance self-concept by calling into question the actions of those who behave differently. This tactic of justifying an action on moral grounds appears to have been used by the Buffalo captain, who claimed to have rejected an attractive interview because, despite being able to support himself during the ten week conversion course, he was unwilling to work for a company who wouldn't invest in their pilots:

"I turned down the job because at the time they weren't paying anything for training…if the company can't invest in their employees as they go through training you know…"
(Ibid., p. 204)

This type of justification reinforces the individual's sense of moral worth whilst downplaying the fact that they didn't get the job. For a pilot, the realisation that one lacks the ability to progress any further professionally is certain to result in cognitive dissonance given that most pilots follow a predictable career path involving routine achievement of professional goals. It is conceivable that considerable adaptation follows such a realisation and for this reason the rationale behind the justification can be complex and well-rehearsed. If such a justification is to fulfill the adaptive objective it must be impervious to any challenge to its truthfulness. Another common tactic is to downplay the importance or attractiveness of the promotion or job in order to justify why one decided not to take it. The Lexington first officer was musing over the possibility of working in the Middle East:

"Maybe to be an expatriate is not a good thing"
"You can't buy property there"
"I wanna start and finish here in the States" (NTSB, 2007a, p. 129)

Justifications in the transcripts were carefully constructed; captains cited lower salaries as a plausible justification for not moving, which effectively differentiated them from their audience because first officers would probably be moving up in terms of salary. Captains never mentioned that they didn't like the idea of being a first officer but it is certain to have been in their mind. Some justifications, although insurmountable, seemed lame: for instance, if one wants to start and end their flying in the USA, don't apply to a Middle East airline. The same pilot also commented that the airline in question had standards that some of their competent colleagues had failed to meet. The fear of failure represents a serious potential threat to self-concept and therefore a strong disincentive to even attempt to move to another airline, but is another justification that very few pilots would admit to. Justifications involving immutable factors such as culture or national identity also appeared to be linked to moral worthiness. By highlighting issues such as the relative absence of certain freedoms or a less relaxed attitude to airline operations a speaker not only justifies their decision but reinforces the notion that the job was not really good enough for them anyway.

"You can't buy land…they'll let you buy a condo but you can't buy property" (Ibid., p. 129)

Justifications such as describing why a favour was done for a colleague often appear to be initiated by the speaker with the express intention of eliciting a favourable response, and that is just what happened in the transcripts. Leonard et al. (1999) differentiated between deliberate processes like the one just mentioned, from reactive processes where individuals react to a perceived threat to their self-concept, sometimes at short notice. In the Buffalo accident transcript the captain is heard rapidly defending himself from a suggestion that he might have supported unethical behaviour in a property transaction:

"So he offered them forty or fifty thousand lower than what they had offered him first…"

"They were trying to get the best they could…just like everyone else does"

(NTSB, 2010a, p. 211)

In this case he made the point that the behaviour described was “just like everyone else does”, thereby reducing his personal support for the behaviour. This adaptation process where personal responsibility is downplayed offers a plausible explanation for the justification of sterile cockpit infringements along the lines “well everyone else is doing it”. This means that if this behaviour is to be changed it is necessary to effect changes in the self-concept of those pilots concerned.

7.1.18 NORMAL FRIENDLINESS ON THE FLIGHT DECK

Normal friendliness usually involved an act of kindness such as flattering, sympathising or sharing a confidence with a colleague; some of the underpinnings of those behaviours have already been outlined in this thesis. The only behaviour type in this category that defied an explanation based upon existing literature was that of making random non-operational remarks. Informal interviews with pilots indicated that the dominant reason that random conversations occurred was the awkwardness associated with long periods of silence between the two pilots. Although the awkwardness of extended silence in interactions is well documented, few researchers have considered the phenomenon of excessive volubility worthy of detailed study because in most contexts volubility is not conceivable as a safety issue. Another mundane but obvious explanation is that because much of what pilots observe during their everyday operational lives is novel and interesting it would seem unusual not to comment upon it. There is also a blurred line between what is operationally relevant and what is not; for instance, an accident flight crew at Dallas conducted a conversation about the presence of birds near the runway (NTSB, 1989, pp. 121-24) which was considered a likely source of distraction but it is conceivable that a discussion related to birds near the runway could be legitimately enacted in quite a similar contextual situation to the one that attracted criticism. It is also relevant to note that most of the interesting things encountered on a flight occur during the sterile cockpit period whereas cruise flight can be quite unremarkable. Communicating interest may also have strategic objectives; research by Sternberg et al. (1981) indicates that lay conceptions of intelligence and competence place considerable emphasis upon clear communications, verbal fluency and displaying an interest in the wider world. In a context where it has been shown that portraying competence is important, it is to be expected that some individuals will seek out ways to achieve that portrayal, and conversation is an obvious medium for its expression. It is also plausible to speculate that there may be both cultural and gender differences in the propensity to conduct small talk. Research by Endrass et al. (2011) comparing Asian speakers with their western counterparts found that Asians tended to speak less about their personal lives. When westerners conducted small talk they tended to communicate their subject matter more explicitly, whereas Asian speakers expected their audience to read between the lines in order to decode the meaning of the message. This meant that western conversations were more likely to involve clarification whereas Asian conversations left much unsaid. Although there were very few Asian transcripts available, in one suitably detailed transcript involving a Singaporean crew at Taiwan (ASC, 2002) there was no conversation relating to any subjects other than the flight, whereas in others involving Indonesian flight crew at Pekanbaru (NTSC, 2003) and Korean flight crew at Guam (NTSB, 2000) there was evidence of social small talk; so there was no conclusive evidence of cultural differences. The American transcripts that represent the bulk of the qualitative data used in the current study contained a considerable amount of social talk. Most Asian countries are high power distance cultures, meaning that conversations between subordinates and superiors may be less free flowing. More research is needed on the influence of culture on sterile cockpit infringement. It may be that the tendency in western airlines to reduce the social distance between captains and first officers has resulted in the undesirable by product that the flight deck has become just another social environment. In terms of gender differences, research by Brescoll

(2011) suggests that male leaders who speak a lot tend to be evaluated as more competent than those who are quieter, whereas female leaders tend to attract negative evaluations if they are excessively voluble. It may also be the case that pilots conducting small talk at inappropriate time are attempting to portray an image that embraces group norms such as being relaxed and competent. There is some evidence from a few transcripts of pilots who appear to be showing off by doing something unnecessarily difficult as was the case in an accident at Guantanamo Bay (NTSB, 1994a), or in a very few cases, unauthorized (NTSB, 2007). This raises the possibility that pilots sometimes talk in order to demonstrate that they are skillful at their job. Research on concurrent task management indicates that talking and performing another task such as driving, uses up cognitive capacity. Steven Davidson (2003) a senior doctor of emergency medicine, commenting upon the multitasking that is a constant feature of his specialty, notes that his colleagues “swagger a bit and are proud of pulling it off” when they face these challenges daily. This supports the idea that demonstrating that one is capable of doing several things at once evokes an impression of competence. A pilot who conducts a mundane conversation whilst flying an airliner might well be enacting just the kind of swagger Dr. Davidson outlined above. This may go some way to explain the incomprehensible behaviour of two pilots at Charlotte who thought it was appropriate to discuss a fairground ride just seventy seconds before crashing into the ground (NTSB, 1975a, p.4). This link between multitasking and supposed competence has been discussed by several researchers (e.g. Glenn, 2010) and is generally thought to be illusory. It may also be relevant that there are clearly occasions when a conversation can be conducted without causing distraction and this has potential to reduce the perceived validity of a blanket prohibition of such conversations. It is also possible that speakers view these conversations as part of their role in promoting crew co-operation, because small talk has been linked to improved morale and rapport in organisational settings (Moutoux and Porte, 1980). Airlines tend to be quite prescriptive about what pilots say and do on the flight deck but research into pilot personality which highlights such features as internal locus of control and extraversion goes some way to explain why on occasions pilots make their own judgments about when it is safe for them to converse.

In summary, this section has proposed that pilots converse on random subjects for a number of reasons. They work in an interesting environment which encourages comment; often there is a blurred line between what is operationally pertinent to talk about and what is not. Personality research indicates that pilots tend to share several personality traits, which makes conversation flow easily. Cultural and gender differences may influence the inclination to converse. Organizational research indicates that conversation encourages morale and rapport so it is easy to convince oneself that conversation is justified. Expressing interest in a wide range of subjects portrays an impression that the speaker is intelligent and competent. FCMs appear to favour a portrayal of relaxed competence which may be reinforced by demonstrating an ability to successfully complete concurrent tasks. The fact that airlines frequently sanction and promote equally distracting practices may lessen the perceived need to comply with the sterile cockpit rule.

7.1.19. CONCLUSION AND IMPLICATIONS OF THE CONVERSATION RESEARCH

The flight deck emerged as a specific working environment with its own conventions and protocols, some of which were sanctioned at a group level rather than an organisational level. This makes the flight deck worthy of ethnographic study in its own right. The inductive nature of this research prompted an orientation towards IM as an explanatory framework, which in turn led to an examination of the influence of the organisation. The insights gained from this study suggest that the influence of organisational factors needs more research. The evidence that group norms are sometimes favoured over organisational norms would seem to warrant examination by both parties. Rules are subject to classification: some rules are prescriptive, while others are proscriptive. Some rules, like those of chess, are constitutive, while others, such as speed limits, are regulative (Sidnell, 2003). The transcripts and anecdotal evidence indicate that the sterile cockpit rule fits firmly into the regulative category because pilots seem to be able to infringe it without catastrophe much of the time. The transcripts also indicate that FCMs feel autonomous whilst in role and that this results in stress when they encounter a rule or some other environmental factor that represents a challenge to that autonomy. It may be coincidental that all four pilots involved in the two most serious accidents examined in this study had considered leaving their current job. This hints at a level of dissatisfaction within commuter airlines that appears to contribute to sterile cockpit rule infringements by driving the conversation. This study went one step further than previous commentary on this subject to propose that such conversation might be an autonomic or involuntary reaction to environmental factors such as industrial issues. If this is the case, it is futile to call for stricter compliance with rules, the working environment needs to change. This study found that cynicism towards the organisation was mostly a crew cohesiveness tactic which could also explain why group behaviour norms appeared to be more dominant than organisational norms. Self-promotion emerged as the most identifiable type of verbal behaviour, with a large percentage of pilots indicating that they had seen it and they understood its purpose. Ingratiation was far more complex than just “sucking up” to the boss; it was broken into six subcategories in the literature and was even more abstract in the aviation context. In defence of the detailed coverage given to ingratiation in this study it should be noted that although it is considered to be a subcategory of IM it has been studied extensively as a construct in its own right.

Locus of control research was highly relevant to the aviation context and it is surprising that so little has been written about this construct as it applies to airline crews. A self-identity feedback loop was proposed in response to the observation from the transcripts that the longest and most detailed conversations were ones that described situations where pilots felt their powerful identity was being threatened. This prompted a discussion about unequal power relations on the flight deck which despite decades of crew resource management (CRM) training are still evident. FCMs will recognise the feeling of stress experienced when factors outside their control result in a five minute delay leaving the gate and wonder why they don't feel the same when they are delayed a few minutes during their everyday life. This study has proposed that it is because when *in role* a pilot expects to be able to control such events and when that is impossible, stress is experienced. The feedback loop proposed in this study is intuitive and could conceivably explain some of the disproportionate reactions to perceived challenges to authority evident in the transcripts.

IM, in particular SP, accounted for more verbal behaviour types than any other factor; this does not mean all pilots are excessively egotistical; rather they appear to be attuned to the strategic use of certain forms of verbal behaviour. This may be because so much of their communication is verbal as a result of the ergonomics of the flight deck. An important factor seems to be the limited time that pilots, sometimes meeting for the first time, have available to make an impression.

The scarcity of relevant aviation-related literature required imaginative reinterpretation of some concepts to fit the aviation context. Despite these difficulties this study found that all of the conversation types were explainable by one or more of the seven explanatory categories developed for this research. Many of the observations made in this research required detailed knowledge of social science and the aviation context. Because this research is original, some of the ideas are new and will inevitably be subject to revision with time. Examples of original areas of research included in this study are:

- The competing influence of group norms versus organisational norms.
- The enactment of mundane conversations as a tactic for crew cohesion.
- The underpinnings of random conversations.
- The potential influence of organisational pressure as a cause of autonomic stress mitigated through conversation.
- The role of airline managements in the maintenance of the self-concept of employees involved in safety critical occupations such as airline flying.
- The potential use of defensive or anticipatory IM by underperforming pilots.

7.2 UNDERSTANDING THE ROLE OF UNCLEAR COMMUNICATIONS IN SFP RELATED OCCURRENCES

The importance of clear communication in aviation operations is highlighted by a recently published study by the UK CAA (CAA, 2017) conducted by an expert in linguistics whose previous research has examined how cabin crew use language to construct and project a professional identity and community, and the associated impact on inter-crew cohesion with pilots. The current research involves linguistics and was conducted by a pilot who has experienced all of the types of miscommunication outlined in this section. Research into aviation related verbal phenomena can on occasions be quite theoretical[x] but this research examined real life instances from the occurrence literature with a direct relevance to the study of SFP. The aim of this research was to identify some of the most recurrent instances of unclear communication in the aviation occurrence literature and propose some reasons for their occurrence.

7.2.1 INTRODUCTION TO THE UNCLEAR COMMUNICATION RESEARCH

This section reports on a study which examined the characteristics of speech acts that have been evident in advance of an aviation safety occurrence in which failed communication was a factor. A detailed literature review indicated that in the aviation context, unclear communication was usually characterised by either excessively mitigated communication, delayed communication, or a combination of both. Much of the existing research relating to failed communication in other institutional settings is concerned with how individuals communicate in contexts such as science, medicine, the law and politics without causing organisational upsets, an orientation dominated by the literature relating to linguistic hedging. A detailed review of a carefully selected corpus of miscommunication related aviation safety occurrences resulted in a focus upon hedged expressions of doubt or uncertainty. By examining CVR transcripts of verbal interactions conducted in advance of a safety occurrence it was possible to identify recurrent instances of hedged communication, many of which have been documented in the linguistics literature. According to UK Civil Aviation Authority research (2014), three of the most recurrent categories of aviation safety occurrence attributable to the actions of the FCMs can be paraphrased as follows:

- Flight below a safe altitude
- Loss of control of the aircraft
- Omissions or inappropriate actions by FCMs

A corpus of CVR transcripts involving each of these categories was examined and hedges were identified by using existing taxonomies adapted for the aviation context.

7.2.2. WHY CLEAR COMMUNICATION IS IMPORTANT IN AVIATION OPERATIONS

Safety systems involving large and complex processes such as airlines rely for their continued safe operation upon clear communications. For instance, misunderstandings between pilots and air traffic controllers have been implicated in some of the most serious documented air accidents. Research involving nuclear power plants (Hirotsu, et al., 2001) found that 25% of operator errors were attributable to inappropriate communications. Railway maintenance operations were even more susceptible to communication related errors, with 92% of such errors being attributed to inappropriate communication (Murphy, 2001). As far as aviation is concerned, Grayson and Billings (1981) found that 70% of the reports they surveyed from the NASA ASRS database involved inappropriate communication. Although the literature review conducted for this study identified extensive research relating to both inter and intra-flight deck communications, as far as is known this study is the first to identify specific recurrent speech acts that have preceded a safety occurrence and to propose explanations for why they were used. Although considerable effort has gone into ensuring formal aviation English is unambiguous, a particularly persistent feature of non-routine communications, such as those frequently heard when things are going wrong, is the tendency towards vagueness and imprecision identified by both Chatham and Thomas (2000) and Morrow et al. (1994). Furthermore, the literature indicates that the vagueness and imprecision characteristic of non-routine communication between aviation professionals very rarely takes the form of exaggeration; on the contrary, there is a marked tendency towards understatement and mitigation.

7.2.3. THE THREAT TO AVIATION OPERATIONS POSED BY UNCLEAR COMMUNICATIONS

Some of the most serious aviation safety occurrences have featured an instance of unclear communication that is identifiable with reference to existing research. Throughout this section examples will be cited but some of the most important are outlined below:

- Two Boeing 747s collided on a runway at Tenerife North airport after both first officer and engineer expressed uncertainty about receipt of a clearance to take off (Netherlands Aviation Safety Board (1978).
- A Boeing 737 crashed in Washington on takeoff after several expressions of uncertainty from the first officer relating to the engine indications he was seeing (NTSB, 1982).
- A Boeing 727 crashed at Mount Teide, Tenerife after indirect expressions of uncertainty from all three FCMs (UK AIB, 1981).

- A Convair 600 captain at Arkansas misled his first officer by asserting that the terrain did not exceed 1200 feet shortly before hitting a mountain at an elevation of 2900 feet. The first officer made multiple expressions of doubt throughout the transcript (NTSB, 1974).
- A Gulfstream crashed short of the runway at Houston after the first officer made a misleading assessment of the aircraft state by stating *"you're all squared away now"* just before impact. The captain expressed doubt about this assessment but continued the approach (NTSB, 2006b).
- A Boeing 757 crashed at Cali one minute after the captain told the first officer *"You're in good shape now".* The first officer had previously expressed doubt about continuing the approach (ACRC 1996).
- A Douglas DC 8 crashed on final approach at Guantanamo Bay after repeated <u>mitigated directives</u> to the captain indicating that his actions would not be successful. Despite several expressions of uncertainty regarding the successful outcome of the flight, the first officer said *"looking good"* just seconds before control was lost (NTSB, 1994a).

The factor that connects these diverse instances is that one or more of the FCMs performed at a substandard level of performance that could have been communicated and corrective action taken in advance of the occurrence but for some reason was not. This study proposes some reasons based upon existing research from a wide range of disciplines. The utility for aviation professionals of being able to identify linguistic markers of doubt or uncertainty is that if corrective action had been taken at the first expression of doubt or uncertainty, all of the accidents cited in this section would have been avoided. Whilst it is understandable that a flight crew will be influenced by many factors to continue or discontinue a course of action, the occurrence literature indicates that there is frequently reluctance of one FCM to communicate unequivocally their doubt or uncertainty to a colleague resulting in no corrective action being taken until it is too late. A detailed reading of many occurrence reports (some of which had not even considered the influence of unclear communications) indicated that most instances could be categorised as follows:

- The speaker was aware something was amiss and did not communicate it directly
- The speaker was unaware or not sufficiently certain that something was amiss and this inhibited communication
- The speaker knowingly miscommunicated information

From this basic categorisation it was determined that the focus of this research would be upon communication that tended to underplay, minimise, ignore or misrepresent the level of uncertainty or doubt felt by the speaker. The most complete body of literature relating to understatement and mitigation is found in research into the verbal construct known as linguistic hedging.

7.2.4. WHAT IS LINGUISTIC HEDGING?

Hedging is a rhetorical strategy that attenuates either the full semantic value of a particular expression, as in:

"I suppose it's alright" spoken by a pilot who was unsure about a holding instruction he had received; the Boeing 727 crashed two minutes later. (UK AIB, 1981, p. 22)

Or the full force of a speech act, as in:

"do you think you're gonna make this?" spoken by a first officer who had serious doubts about the captain's conduct of a visual approach at Guantanamo Bay which resulted in a crash (NTSB 1994, p. 123).

Earlier in this thesis it was suggested that aviation professionals in general, and pilots in particular can be considered to be part of a social group with its own rules and conventions so it was illuminating to note that of the ten pilots who were interviewed during the development of this research, none was familiar with the concept of hedging in relation to communication. If pilots are unaware of the ubiquity of hedging in flight deck communication it is almost certain that those who support them are also unaware. This means that the information in this study is likely to be highly relevant to both pilots and to the wider aviation community. Furthermore, although several occurrence reports have commented upon the attenuated communication that has preceded an occurrence, as far as is known, no attempt has been made to operationalise the construct in the aviation context. There follows a brief review of what is known of communicative hedging from research involving a wide range of research populations.

According to Brown and Levinson (1987) a hedge is a particle, word, or phrase that modifies the degree of membership of a predicate or noun phrase…it says of that membership that it is partial, or true only in certain respect; or that it is more true and complete than perhaps might be expected. (Ibid., p. 145).Their contention was that during ordinary communication, a threat to co-operative communication is posed when a speaker expresses ideas or opinions too forcefully in case they are unpalatable or threatening to the addressee. In their view, the action of hedging, by avoiding commitment to such ideas and opinions represents a primary and fundamental method of disarming routine interactional threats (Ibid., p. 146). Although hedging is considered an aspect of pragmatic competence that can express both reinforcement and attenuation, in line with Brown and Levinson and others, the description of hedging in this section concentrates mainly on its role in attenuating the force of verbal discourse because that is where the transcripts indicate miscommunication tends to cause most serious problems during aviation operations. There follows a detailed explanation and some real life examples of the diverse types of hedged communication that various researchers have identified.

PROPOSITIONAL AND RELATIONAL HEDGES

Prince et al. (1982) made a clear distinction between two types of hedging; the first concerns the propositional content and expresses the extent to which the speaker believes the information they are communicating can be considered true or otherwise (propositional hedging). A propositional hedge creates uncertainty in the propositional content by emphasising non prototypicality with respect to class characteristics, as in the extract below spoken by the captain involved in a CFIT accident at Mount Teide, Tenerife:

"*Strange hold isn't it… doesn't parallel with the runway or anything"*

(UK AIB, 1981, Annex A/2)

Here the comment that the holding pattern was oriented in an uncommon fashion marked it as a non-prototypical example of a holding pattern. A propositional hedge can be clearly identified if it is possible to insert the prefix "*I am sure…it doesn't parallel the runway or anything"* without changing the meaning. In the example above, the *propositional hedge* performs the function of indirectly communicating that although this is a holding pattern, it is not a typical example and perhaps some doubt or uncertainty about its safety exists. The investigation from which the extract came cited the lack of clarity in the definition of the holding pattern as a contributory factor in the resultant CFIT accident. The report also commented that the first officer's comment "*…that's an odd sort of one…"* was one of three unheeded intra cockpit expressions of doubt or uncertainty that immediately preceded the crash.

Prince et al.'s (1982) second type of hedging strategy related to the degree of commitment a speaker is willing to commit to the propositional content being the truth; this is known as a *relational hedge.* In the example above, the speaker didn't express an opinion about the holding pattern except to indirectly point out that it was unusual. Relational hedging differs insofar as it expresses the speaker's relation to the truthfulness of what is being said. The FCM cited in the extract above used a relational hedge later in the same sequence when he used the phrase "*suppose it's alright"* to express his tentative commitment to the actions he was witnessing. Unlike propositional hedges, relational hedges cannot be prefixed by a phrase such as *I am sure* because of the presence of phrases such as *I suppose* or the more common (in the occurrence literature) *I guess.* There is one exception to this rule; this is the *attributive hedge*, in which the speaker attributes the information being communicated to some other source to emphasise the authority of what is being said. In other words, I am only communicating what a particular source said, as was the case just before the accident at Tenerife.

"They want us to keep going more round don't they?" (UK AIB, 1981, Annex A/2)

Attributions are not limited to human sources; in the Chicago transcript, during a discussion about landing on a snow covered runway the first officer emphasised that the *book* authorises an action but with an implicit expression of doubt tagged onto the end:

"I mean the book says you can as long as it's positive…but man that's whoo"
(NTSB, 2007b, p. 94)

Attributive hedges can also be used to lessen the force of the information being communicated by being vague or imprecise about the source of the information, as in:

"They say it's better than we could ever be" spoken by the Chicago first officer as he tried to persuade his reluctant captain to use the autobrakes for landing (Ibid., p. 141). In this case the speaker appears to be citing information from an unspecified source that he is merely passing on and should not be held accountable for any inference gained.

APPROXIMATORS AND SHIELDS

Prince et al. (1982) subdivided hedges into two distinct types, APPROXIMATORS and SHIELDS.

APPROXIMATORS

Approximators operate on the propositional content and function to express the extent to which the item under discussion is representative of its prototype. These approximators are further divided into ADAPTORS and ROUNDERS.

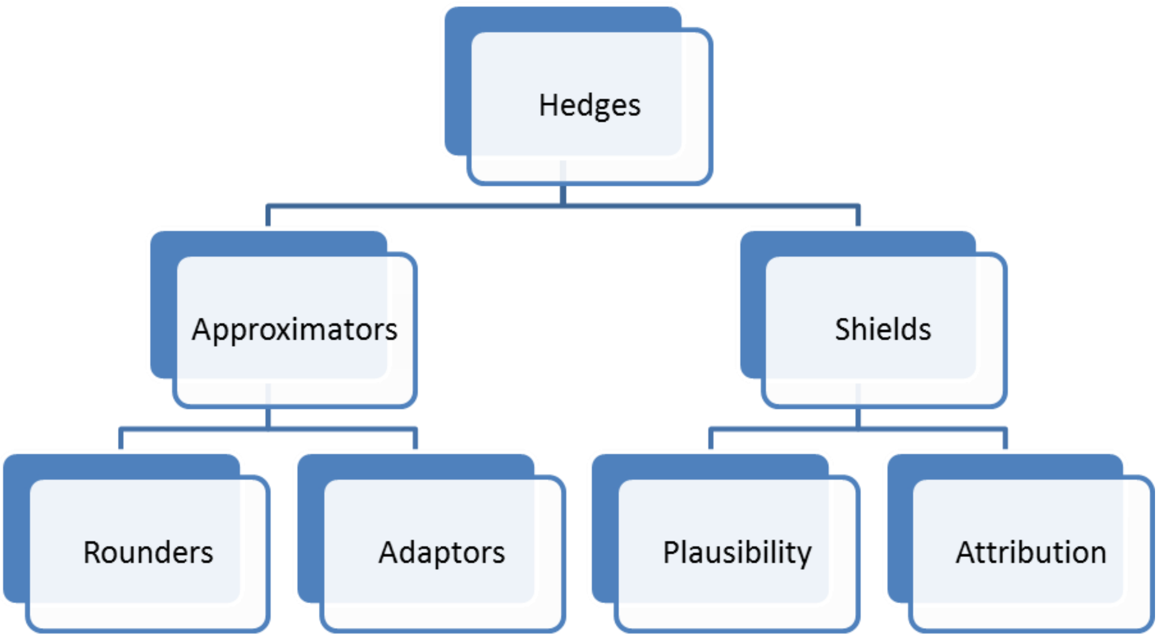


Figure 7.3: Prince et al.'s subdivision of linguistic hedges

ROUNDERS

Rounders function to modify a numeric value by communicating it with an inappropriate degree of precision as in this comment from the Arkansas captain:

...the highest point out here is ***about*** *twelve hundred feet…* (NTSB, 1974, p. 36)

ADAPTORS

Prince et al. (1982) coined the term “adaptors” for expressions such as sort of (sorta), kind of (kinda), a bit or a little bit, which tone down or decrease the effect of a scale word (Leech and Svartvik, 1975, p. 101) such as, in the aviation context, slow, fast, high or low. In the transcript of a flight crew who crashed on landing at La Guardia airport the pilot monitoring (PM) is heard to use the adaptor *“little”* four times in the twenty seconds before the crash (NTSB, 1997b, p. 22) A more recent report into an accident at San Francisco reported clear evidence of misunderstanding between the FCMs after use of the phrase “this seems a little high” by the PM (NTSB, 2014a, p. 176). When precise language is used it is clear what action must be taken but when vague language is used, a context in which a flexible attitude to rule infringement can develop. In the extract above, the Arkansas captain communicated information that required precision, in a highly imprecise way insofar as it did not state an exact terrain elevation and was further hedged by the comment in the extract below that “he believed” that the terrain was in a different location as well:

“The whole ***general*** *area…and then we're not even where that is…I don’t believe”*
(NTSB, 1974, p. 36)

At Arkansas the pilots had lost positional awareness which meant that accurate terrain information was not known, which probably explains the use of imprecise language.

Earlier in this section it was suggested that imprecision can be used to facilitate a rule infringement, and this should be explained. By using an adaptor such as “a little” the speaker avoids explicitly quantifying the extent of the deviation, which is always explicitly defined by an operator. For instance “a little fast” might not result in corrective action whereas “twenty knots fast” would require a missed approach if the specified range was a maximum of fifteen knots. It could also be argued that the term “little” indirectly communicates the speaker’s assessment of the situation as being acceptable, thereby tending to support an infringement in a way that would not be possible if more explicit language was used. The inappropriate use of the downtoner “little” was prolific in the transcripts.

SHIELDS

The second type of approximator proposed by Prince et al. (1982), the SHIELD is separated into two types, the PLAUSIBILITY SHIELD and the ATTRIBUTION SHIELD.

PLAUSIBILITY SHIELDS

When a speaker uses a plausibility shield the intention is to indicate that they are not completely sure about the content of the proposition being made. By using phrases such as *I think…it looks like, probably, as far as I can tell,* they signal a tentative or cautious assessment of the truth of what is being said. It has been suggested by Hubler (1983, p. 18) that by using a plausibility shield, speakers shield themselves from the degree of liability they might face if the proposition was expressed with more force. Prince and her colleagues noted that the physicians they observed made extensive use of plausibility shields when diagnosing illnesses and planning courses of treatment that could leave them in a position of legal liability. In the aviation context the plausibility shield operates to protect the speaker’s plausibility should the proposition turn out to be incorrect, in effect to be able to assert “I didn’t say that for certain”. This type of tentativeness also shields a pilot from an admission of a deficit in understanding or experience.

EXAMPLES OF PLAUSIBILITY SHIELDS AND THEIR SUGGESTED FUNCTION

"I GUESS"

I guess was apparent in the transcripts during attempts to persuade a colleague and also during periods where inter crew agreement was tentative. It was also used during instances of loss of positional awareness, seemingly to disguise the extent of disorientation. *I guess* was also used to indirectly pose a question without the speaker having to reveal their opinion until they knew more about the addressee's point of view. Although *I guess* is not restricted to transcripts from the USA it has been noted that it is most frequently used in American English (Van Bogaert, 2009, p. 421). *I reckon* appears to perform a similar function for native English speakers and was also evident in transcripts from Australia and New Zealand. Although research such as Kaltenbock (2013, p. 6) demonstrates a marked decline in certain comment clauses and a rise in others, the aviation context seems more stable with examples of *I guess* performing familiar functions over several decades. A persistent thread is the focus upon politeness enacted by avoiding impinging on the other's freedom to act in a way they see fit. This concept is known as face threat avoidance and whilst almost undocumented in the aviation literature it is a well understood psychosocial construct. A response that dismisses the speaker's suggestion poses negative-face threat to the addressee so the least that needs to occur is a consideration of an incoming suggestion. The extract below, from the Chicago accident is an example of a tentative captain being persuaded by his first officer:

"…well keep talking ***I guess we could do*** *it let's, let's see what the conditions are up there… we'll do it"* (NTSB 2007b, p. 142)

This extract suggests that *I guess* is used at the conclusion of a decision making process in which a range of options of differing acceptability have been considered. It often comes with a sense of reservation, as in the example above, where the speaker still signals tentativeness by using "*could do it.*"

The extract below was part of a lengthy exchange in which the first officer justifiably attempted to persuade his captain to use the automatic brakes.

***"I guess** if you use max…it'll get your attention"* (Ibid., p. 82)

The first officer avoids saying how it might get your attention. The mitigation was likely enacted to avoid negative-face threat to the captain. Given that the persuasion was justified, it is excessively mitigated.

In the extract below, the Detroit accident captain was reluctant to admit that he was lost during taxiing so he appears to have made a tentative assessment on the off chance that it might be correct. In the verbal exchange that followed this he admitted that he wasn't sure.

***"I guess** we turn left here"* (NTSB, 1991b, p. 135)

The statement below was interpreted as a question by the investigators, who inserted a question mark after the tag *huh*? This supports the notion that a speech act that appears to be a statement can also function as a question. The function of such a linguistic device is that it avoids directly asking the question, thereby allowing the speaker to assert to himself and to others that no uncertainty existed. Although this may seem deceptive, it is possible that such a device is used subconsciously to meet the face wants of the speaker.

"…until the yellow line ***I guess*** huh?" (Ibid., p. 133)

"I SUPPOSE"

Although *I suppose* featured far less frequently in the transcripts than *I guess,* the incidence of the former in the close proximity of a catastrophe at Tenerife demands its consideration. Only one clear instance of *I suppose* was found in the corpus transcripts but its positioning as the last meaningful verbal input from the speaker suggested that the speaker had given up expressing his uncertainty.

"...I ***suppose*** *it's alright..."* (UK AIB, 1981)

In a search for some supporting evidence for the use of *I suppose* as a marker of resignation the following extract was located in which the first officer at Palmerston North expresses his doubt about a clearance and the captain, quite reasonably decides not to challenge it, leaving the first officer to signal his tentative agreement with the clearance.

F/O *"That's not right is it?"*

Captain: *"Yeah, we won't argue"*

F/O: *"Oh well,* ***I suppose*** *we can be out here at five thousand anyway"* (TAIC, 1995, pp. 121 122)

"SHOULD BE"

The term *should* is a member of a hierarchy of <u>modal verb</u>s that express various levels of certainty. The modal verb *should* occupies a position near the top of that hierarchy in that it is intended to express a strong likelihood that the proposition being made is correct.

"Mount Erebus ***should*** *be here"* (TAIC, 1979, p. 73)

It is not clear who made the remark above but the transcript suggests that they were involved with navigation in proximity to Mount Erebus which the aircraft hit. Although an uncertainty marker, the term *should be* indicates the speaker's expectation that the proposition is likely to be correct.

*"...visibility **should** pick up closer to the surface..."* (NTSB 1994 p. 109)

The extract above indicates that visibility was not very good at the time of speaking whilst crucially implying intent to proceed on the basis of an expected improvement. If the speaker had used *might* or *could* a completely different, more tentative message would have resulted. Comments including an assessment that implied an expected improvement in the current situation rarely resulted in corrective action as in this extract from the Detroit runway collision accident report:

*"...this **should** be runway nine two seven..."* (NTSB, 1991b, p. 145)

This speaker was referring to his position in relation to runway 09/27; the term *should* signalling that although the speaker was unsure of the proposition he was more certain than if he had used *might be* or *could be.* Given that it was critically important to know the position accurately a statement including *this could be* would be an admission of substandard performance that would not be a preferred option for the speaker due to positive face threat.

"IT MIGHT"

The modal verb phrase *might* is more tentative than *should.* In the first extract below, from the Guantanamo Bay accident, the speaker has no way of knowing the extent of the depth perception issues so is understandably vague. In the second extract the Detroit first officer is alerting the addressee to the possibility that taxiway "oscar six" may have been missed during taxiing; if in fact it had not been missed, positive face threat had been avoided in a way that would not have been possible if an unequivocal statement that the speaker was unsure of his position had been made.

*"It **might** give you some depth perception issues"* (NTSB, 1994, p. 102)

*"We **might** have missed oscar six"* (NTSB, 1991b, p. 139)

"I THINK"

It has been suggested that in everyday interaction the term *I think* has undergone semantic bleaching, meaning it has lost its force as an uncertainty marker (Kaltenbock, 2013). The transcripts supported this contention insofar as *I think* had multiple functions depending on its positioning within a phrase, the linguistic devices that surround it and who used it. The example below, from the Mount Erebus accident used the progressive tense in conjunction with the adverbial phrase *just thinking*, which has been identified as a strong uncertainty marker, in this case expressing justifiable tentativeness.

"I'm just thinking *about any high ground...**that's all"*** (TAIC, 1979, p. 70)

With increased potential for face threat, mitigated communication tends to increase. This exchange apparently signalled that the speaker was no longer confident that terrain clearance was assured. A body of research by Bavelas (1985) has examined how when speakers are faced with few communicative options they tend to use unclear or equivocal language. The speaker above was faced with what Bavelas referred to as avoidance/avoidance conflict (hereafter AAC) where failing to speak up was not an option but challenging this senior captain was face threatening. The softening adverbial *just* and the tag *that's all* both understate the seriousness of what was a legitimate expression of concern. The phrase *I think* has also been identified as a means of expressing confidence or certainty when used by those with high status (Holmes, 1990: p 187), which makes *I think* a very complex phrase given the hierarchical nature of the flight deck.

*"**I think** we'll start down a little early here"* (Ibid., p. 40)

The extract above (spoken by the Mount Erebus captain) stands in stark contrast to the previous highly mitigated use of *I think* spoken by one of his subordinate FCMs; a general observation from the corpus transcripts and the literature was that subordinate FCMs used more attenuated communication than captains.

Holmes also suggests that in the initial position *I think* can signal reassurance, whereas in the final position it is exclusively associated with tentativeness; she also proposes a role in terms of negative-face threat achieved by avoidance of being too rigid in one's opinions, in metaphorical terms, not stepping on others' toes. It also appears to perform the communicative function of attempting to alert an addressee not to rely too heavily on what is being said, presumably to spread the accountability if an error is being made. In other cases it appears to seek to elicit an opinion from an addressee by expressing the speaker's assessment of the situation in such a way that does not impede the freedom of action of the addressee.

***"I think** we need priority"* (NTSB, 1991a, p. 177)

This was one of several direct comments made by this flight crew to ATC at New York JFK airport, including "*we are running out of fuel"*, none of which were heeded. In this case, the seriousness of the situation depended upon effective interaction between ATC and the flight crew. A flight crew who declare that they have allowed a critically low fuel situation to develop that disrupts a major airport will undoubtedly face consequences so a tendency towards understatement and mitigation is understandable so that if the most optimistic outcome occurs they can deny their substandard performance to both the outside world and to themselves. This type of denial has face-threat avoidance and a self-esteem maintenance functions.

The two extracts below came from the Detroit flight crew who became lost in fog almost as soon as they commenced taxiing out. The first extract signals that the speaker is uncertain about the position of the aircraft; this is certainly how it was interpreted by the addressee.

*"**I think** we are on x ray now"* (NTSB, 1991b, p. 144)

*"I **think** we **might** have missed Oscar Six"* (Ibid., p 139)

The second extract, made to ATC, is an example of a compound hedge; the additive effect of *think* and *might* makes this a highly hedged communication, nonetheless the controller failed to identify this and a runway collision ensued.

"I BELIEVE"

The linguistic literature makes no clear distinction between thinking and believing but in the extract below, the speaker stopped using the term *I think* and used the term *I believe* coincident with becoming uncertain of his position. There is no strong evidence of a clear distinction between the two linguistic devices but *I believe* was uncommon in the transcripts. There is little doubt that the examples below were mostly enacted to convey uncertainty and elicit assistance when the Detroit flight crew found themselves unsure of their position close to an active runway.

*"**I believe** we are at the intersection of taxiway x ray and runway 9/27"* (Ibid., p. 148)

*"**I believe** we are…we're not sure"* (Ibid., p. 151)

"IT SEEMS" and "IT LOOKS LIKE"

These introductory verbs are uncommon in the transcripts but where they do occur they have been associated with a very serious occurrence. The comment below preceded the crash of a Boeing 777 at San Francisco in 2012:

*"**Seems** a little high"* (NTSB, 2014a, p. 176)

This is a highly imprecise comment where it is not clear what is being referred to or even whether it is actually high or just seems to be. This comment was considered by the NTSB to have confused the pilot flying (PF) contributing to a landing accident.

The extract below from the Detroit captain referred to the visibility during taxiing out, suggesting that it was almost zero.

*"**Looks like** it's going zero zero out here"* (NTSB, 1991b, p. 134)

This comment expressed the captain's doubt that the visibility being reported by the tower was correct. He was careful not to explicitly state the visibility because that would rule out a takeoff. The response from the first officer was also non-committal and appears to shift responsibility for the decision to ATC.

*"Oh yeah **I think** they'll tell us"* (Ibid., p. 137)

ATTRIBUTION SHIELDS

Prince and her colleagues' second type of shield, the attribution shield is used to attribute either the degree or quality of the knowledge being expressed, to a third party. Examples of an attribution shield include phrases like *according to* or *they say…* and in common with the plausibility shield it performs the function of distancing the speaker from what is being said, in this case by attributing the source to someone or something else.

THE ROLE OF ATTRIBUTION SHIELDS IN AVIATION MISCOMMUNICATION

This section examines how varying the precision expressed in communication can manipulate the degree to which a speaker can be held accountable for what is communicated.

PRECISION

Excessive precision seems an unlikely source of miscommunication and for this reason no previous research has addressed the phenomenon. However, two very serious runway safety occurrences appear to have resulted from the strategic communication of information that was either excessively explicit or excessively precise. It was suggested in the St Kitts report (UK AAIB, 2010a. p 24) that the provision of a "*broad hint*" from the air traffic controller relating to the flight crew's runway entry point length should have been an opportunity for the flight crew to identify that they were making an error. In another serious incident at Manchester (UK AAIB, 2006b, p. 32) it was noted that the provision by the air traffic controller of precise information relating to the available runway distance represented a missed opportunity for the flight crew to notice that they were lining up for takeoff at the wrong position on the runway. This assessment implies that the controller provided this extra information as an indirect means of communicating his doubt about the flight crew's position on the runway. If this was the case, the communication did not achieve its objective. The two extracts below are both abbreviated extracts of communications from ATC to flight crews who were lined up at the wrong position on the runway prior to departing. In both these occurrences, the first at Manchester and the second at St Kitts, a crash was only avoided by luck.

*"**If you're happy with that**, that gives you er sixteen seventy metres"*
(UK AAIB 2006b, p. 32)

*"Speedbird 2156 **do you not** request err backtrack runway 07?"* (UK AAIB 2010a, p. 24)

A detailed knowledge of aviation communications is not necessary to understand the important features of these examples of miscommunication. Firstly, air traffic controllers never normally advise flight crews of the length of the runway as they enter it, and secondly they rarely question flight crews about whether they need to backtrack (taxi down the runway in the reverse direction to takeoff) a runway unless they are not complying with their cleared route to the takeoff position; all pilots know this. Both the exchanges above broke the fundamental rule of the cooperative principle of communication outlined by Grice (1975), namely that speakers should strive to ensure that what they say furthers the purpose of the conversation. Grice's *Maxim of Quantity* requires that a speaker only include information that is required for the purpose of the exchange; the information provided by the controllers exceeded what was normally required in the prevailing context. Grice also highlighted that the information must be true in order to comply with his *Maxim of Quality*. Although nothing in the content of either of the communications above was untrue, in both cases there was evidence of doubt in the communication from the air traffic controller. Arguably the most important feature of these two instances of miscommunication was that the question being indirectly asked by the controller should not have been necessary if nothing was amiss. So whilst the information communicated was not untrue, it failed in its communicative purpose of informing the flight crew that they appeared to be lining up for takeoff at the wrong position, so it did not meet Grice's *Maxim of Relevance*. A more effective strategy would have been to directly state that the aircraft appeared to be at the wrong position on the runway but both these serious occurrences (one at Manchester, UK and one at St Kitts) indicate that for a variety of reasons, individuals from a wide range of cultures who provide support to flight crews sometimes feel reluctant to directly inform them when they have doubts that if expressed directly might imply they were making an error. The reasons why controllers feel inhibited to correct flight crews when they appear to be making a mistake are likely to be complex but the serious incident at St Kitts (UK AAIB, 2010a) and the fatal accident at Birmingham, Alabama (NTSB, 2014b) suggest that aspects of the hierarchical structure of the aviation system, where flight crews tend to be near the top may be a factor affecting the clear communication of doubt and uncertainty. A similar phenomenon has been documented in the medical profession (Srivastava. 2013) where junior doctors have reported withholding critical information from a surgeon on the assumption that their more senior colleague would be certain to have been aware of the information, only to find out later that the surgeon expected to be told such information. From the insights gained from the two investigation reports into the occurrences at Manchester and St Kitts, the need to avoid threats to the negative face of the flight crew appears to have been an important influence. In fact, the occurrence literature indicates that the addressing of the face wants of a flight crew member who is making an error of judgment is one of the main reasons why subordinates attenuate their critique of a colleague's actions. Although a detailed description of the various face-wants of individuals is outside the scope of this thesis, it can be deduced from testimony from the reports into the Birmingham, Alabama accident and the serious occurrence at St Kitts that support staff are attuned to the concept of "negative politeness" (See Brown and Levinson, 1987, p. 317 for an explanation) which is founded upon avoidance of interfering with an interactant's freedom of action. Several recurrent patterns were evident in the transcripts; firstly a reluctance to speak up that persisted far too long, and in some cases even to the point where the situation was irretrievable. Secondly, there appeared to be a point in the proceedings where even if attenuated criticism was evident, it diminished once it was clear that no corrective action was being taken. There were no documented instances of an unequivocal order being given that resulted in corrective action. There was also some evidence that once a speaker considered that they had done their best to communicate their doubt or concern, there was a point where they appeared to relinquish responsibility for the outcome. In the two serious runway occurrences just cited, the controllers appeared to use precision as a linguistic deresponsibilizing device thereby transferring complete responsibility for an action to the flight crew along the lines, I've outlined the situation as I see it, now it's up to you. Although this may be rational behaviour it is certainly not appropriate for a high reliability context such as aviation. Although, as far as is known, the notion of using language as a means of denying accountability has never previously been identified as a phenomenon affecting flight safety, Holmes (1984, p. 61) has identified the potential for language to be used as a deresponsibilizing device in other contexts, citing research by Brown (1980, p. 128). Although Brown's ethnographic research was far removed from the current region of interest, the concept of language use as a deresponsibilizing device has been applied to a study of aviation manuals, where Sarmento (2005) suggested that the use of the modal verbs "*may*" and "*can*" perform such a function. The topic of attribution of responsibility is a recurrent strand in the instances of attenuated communication in this section.

IMPRECISION

A proposition is imprecise or vague when it is represented as uncertain by a speaker. The use of vague language in the aviation discourse examined for this research is so repetitive in nature that its occurrence is unlikely to be attributable to chance. The notion that vagueness can be strategically deployed is one that has been examined by Jucker et al. (2003) who proposed a variety of reasons, some of which have been applied in this section to specific aviation related instances from the literature. It is noticeable in various transcripts how pilots make extensive use of metaphor and quotation to express ideas vaguely. By describing something that one has been told by someone else or a metaphor relating to someone else's experience, some distance is placed between the ideas being expressed and the speaker, meaning that the speaker is not directly vouching for its veracity. Vague language does not attempt to accurately describe a situation but invites the addressee to interpret what is being offered and reach their own conclusion. This notion, proposed by Sperber and Wilson (1991, p. 546) is particularly relevant in aviation operations where many of the decisions FCMs make are not clear cut but subject to interpretation. This represents a problem, particularly for subordinate FCMs or support staff whose primary task is to advise their hierarchical superior when they doubt the wisdom or correctness of an action being taken. One strategy evident in the transcripts is to provide a metaphor that supports the perspective the speaker wants the addressee to adopt. In line with the cooperative principle outlined above, it may be beneficial to limit the amount of specificity to the minimum necessary to achieve the communicative objective. The extract below details part of a verbal exchange in which the Chicago first officer appeared to doubt the wisdom of using manual braking in the prevailing conditions but needed to convince his reluctant captain to use the automatic braking system (hereafter autobrakes) without posing a threat to his negative face.

"I guess if you use max…my buddy flew 747s for Atlas and he said when you land it'll get your # attention" (NTSB 2007b, p. 82)

The *getting your attention* metaphor [xi]above is not uncommon in aviation discourse. In this case it relates to someone else's experience on a different type of aircraft at an unspecified airport; furthermore no precise comment about the stopping capability is made, merely that *it will get your # attention.* From an experienced pilot's perspective it can be stated with some certainty that what was intended to be communicated was that the brakes would be applied with some force by the autobrake system. It is also likely that despite the use of metaphor, this is how it would be interpreted by the addressee. Nonetheless, from the speaker's point of view no personal opinion has been voiced so it is up to the addressee to decide. Furthermore, it is not at all clear what the "*it"* that will get you attention is. The use of metaphor allows the speaker to avoid committing to an opinion in case it proves to be incorrect or it conflicts with the opinion of his superior. Furthermore, it avoids the speaker imposing an opinion whilst also protecting them from having a proposal dismissed, which would be face threatening. Whatever the reasons, this communication lacked clarity at a time when clarity was essential. In a further attempt to convince his captain the exchange below occurred.

*"**They say** it's better than we could ever be"* (Ibid., p. 141)

At face value this seems a fairly comprehensible assertion that the autobrake system applies the brakes better than a human being could, but whose words are these? The use of the expression "*they say"* implies that more than one, maybe many sources hold this view. It is equivalent to a spoken agentless passive insofar as the term *they* is not intended to implicate any individual or group; what it may seek to do is to de-emphasise the necessity to scrutinise this view because it represents the conventional wisdom on the topic.

There also appears to be a strategic role underlying the use of vague representations of amounts such as fuel quantities, fuel endurances, safety altitudes and others. The three extracts below were spoken by a DC 8 flight crew at Portland who ran out of fuel after becoming distracted by a minor landing gear indication issue.

"Give us ***three or four*** *thousand pounds"* (NTSB, 1979, p. 40)

"We got ***about three on the fuel*** *and that's it"* (Ibid., p. 49)

"figure ***about another fifteen*** *minutes"* (Ibid., p. 40)

The rounder *about* fifteen minutes was probably an indication that the speaker either didn't know how long it would be before they could land or that he didn't consider precision a priority. In fact precision was critical, evident from the unheeded reply from the engineer.

"Not enough…Fifteen minutes is gonna really run us low on fuel here" (Ibid., p. 40)

Although the term *really* would seem to unequivocally signal urgency, the warning from the flight engineer went unheeded by the captain. What should have been communicated was that the aircraft would be almost out of fuel in fifteen minutes. In fact the use of *fifteen minutes* in the initial communication has some significance; according to Dubois (1987) quantities expressed as multiples of five tend to be approximations rather than precise estimates, making the phrase "*figure about fifteen minutes"* a highly hedged communication. Although it was implausible that the captain's intention was to run the fuel so low, to explicitly advise him would represent a face threating act. This is a further example of AAC (run out of fuel versus challenge the captain) as conceptualised by Bavelas (1985). AAC has been linked to instances of complete withdrawal from communication, which was the outcome in this case. The potency of AAC is evident from the fact that in this case the engineer appears to have allowed the captain to run out of fuel rather than inform him directly of his concerns.

The following extract is from the Arkansas accident in 1973 in which the flight crew were avoiding thunderstorms which required them to deviate from their planned route. This type of operation requires a dynamic understanding of the spatial environment (See Chapter 8, the spatial awareness strand of this research), in particular the elevation of the terrain. Although this transcript is old it remains relevant because as this thesis is written, airliners still crash into high terrain despite modern technology.

In response to concerns expressed by his co-pilot the captain asserts:

"The highest point is ***about twelve hundred feet****"* (NTSB, 1974, p. 36)

The imprecision here relates to the means by which terrain height is used during aviation operations. Flight crews can only make very limited use of actual terrain data alone. An analogy would be if drivers were allowed to invent their own speed limits based upon the straightness of the road or the time of day. By referring to the terrain in this way the speaker avoids the necessity of justifying flying below a specific safe height. Notably, just before impact the first officer referred to the terrain using precise language.

The extract below relates to a controversial CFIT accident at Mount Erebus, Antarctica. Although some of the transcript content has been disputed, the extract presented here is not in dispute.

*"**We might** have to pop down **to fifteen hundred here I think"*** (TAIC 1979, p. 71)

This is an unusual exchange inasmuch as the term "*pop down"* introduces a level of informality highly inappropriate for a descent in the vicinity of high terrain. It is also highly hedged, with the downtoner "*we might"* at the beginning and at the end the tag "*I think"* which, as was demonstrated earlier, is associated with tentativeness.

The extract below is from a CFIT accident near Jakarta where a Russian test pilot was demonstrating and promoting a brand new airliner, the Sukhoi Superjet.

"No problem with terrain at this moment" (KNKT, 2012, p. 32)

<u>Bald-on-record statements</u> like this captain's comment on the terrain are uncommon in the aviation context but they are known to take little account of the face wants of the addressee. In such a case it is likely that the addressee will be inclined to agree with the proposition.

"Ya it's flat" (Ibid., p. 32)

Once again it is not clear what *it* refers to and what *flat* means. Zhang (2015: p 52) actually cites the term *flat* as an example of vague and imprecise language, noting that although "*Holland is flat"* there are hills. Sperber and Wilson (1991: p. 182) also point out that this type of vague language also has no sharp conceptual boundary but a continuum; so flat could be *quite flat, very flat* or, as was the case here, not very flat at all. Although the Jakarta accident is the only example of the use of *flat* to describe terrain elevation, the Arkansas accident captain also described the terrain in vague terms before a CFIT accident.

When flight crews become unexpectedly unsure of their position they cannot stop and have a think about the problem, it is a dynamic situation that needs to be rectified promptly. This sometimes results in communication that is highly imprecise, probably because the necessary information is not available to the speaker at the time. The extract below is from an American Airlines flight crew who flew into a mountain in Cali, Columbia after an unexpected route and runway change.

Captain: *"Let's press on to…"*

Co-pilot: *"Press on to where though?"* (ACRC, 1996, p. 33)

To demonstrate the persistence of this phenomenon, the extract below is from the previously cited Arkansas flight crew from 1973:

Captain: *"Keep on trucking', just keep on a trucking"*

Co-pilot "*Well we must be somewhere in Oklahoma"* (NTSB, 1974, p. 34)

The slightly sarcastic remark from the co-pilot was the culmination of over fifteen minutes of attenuated expressions of doubt, and marked a transition from unclear to more direct communication but it was far too late to avoid flying into the terrain. The examples above all involved flight crews who had lost positional awareness so it is likely that the speakers did not have the necessary information to be more precise. In other cases a speaker may possess incomplete knowledge or be insufficiently confident in their own assessment of a situation to communicate with certainty. Speakers may also communicate an opinion or assessment of a situation in such a way that their assessment should be discernible from what is said, whilst still leaving the addressee some room to make their own judgment. This is not always effective, as was demonstrated by the absence of corrective action in response to the sarcastic comment cited above. Although the model of flight crew interaction presented in these examples may seem haphazard, aviation is characterised by situations that are frequently a matter of opinion rather than fact. In the extract below, a first officer involved in the Detroit accident was almost certainly intending to communicate to his captain that he did not consider the visibility to be adequate for the takeoff about to be performed.

"Definitely not quarter of a mile…but at least they're calling it" (NTSB 1991b, p. 97)

When comments such as this are made by captains they are often a statement of intent whereas for subordinates they are put out there for consideration. Much is at stake when a subordinate communicates doubt or uncertainty; dismissal of the assessment poses negative-face threat to the speaker, whilst being too forceful poses positive-face threat to the addressee. In this specific case, an incorrect assessment by a subordinate could impinge significantly on the operation if the captain's assessment was that the visibility was good enough to depart. In this case it is understandable why the speaker gave himself a way out by mentioning that ATC were assessing the visibility as acceptable. Notably, also the speaker did not explicitly state that he thought the visibility was less than a *quarter of a mile;* merely that it was not a quarter of a mile. Although this may seem a small detail, research by Jucker et al. (2003) found that addressees usually understand such a communication as representing a symmetrical range around the stated value that varies depending on what the information is to be used for. In this case the assumption is that the speaker meant to communicate that he assessed the visibility to be less than the stated value but he was careful not to say so explicitly. It was speculated above that the motivation for the vague language was to avoid impinging upon the captain's freedom of action, but in other cases such as the accident at Arkansas it is likely that imprecision was used to avoid explicitly stating the minimum safe altitude because to do so would acknowledge that a rule infringement was occurring or likely to occur. Sometimes merely stating that something is better than some arbitrary value is enough to convey that an addressee should not worry and just accept what is being proposed. This type of imprecision was rarely expressed in numeric terms in the corpus but more usually by a vague description as in the two extracts below from the Arkansas and Chicago flight crews respectively:

"You can quit worrying about the mountains because that'll clear everything over there" (NTSB, 1974, p. 30)

"I know they work better than we do" (NTSB, 2007b, p. 140)

In the first extract, unfortunately the speaker was quite wrong in his assertion about clearing the terrain. In the second, the speaker is advocating the use of the automatic braking system by communicating that in his opinion it would be more effective than operating the brakes manually but without specifying how much more effective. The process of expressing either a high or low value is not restricted to explicit terms such as the "*sixteen seventy metres"* outlined earlier in the Manchester incident; the occurrence literature indicates that some of the most serious infringements or dangerous situations have featured the most imprecise language. In the extract below from the Houston accident transcript, the first officer was probably intending to communicate that the aircraft was being flown at least sixty knots faster than appropriate for the final approach. If this information had been communicated with the appropriate level of precision the pilot flying would have had a strong indication that his actions were not acceptable and a DC 9 would not have landed with the landing gear retracted.

"…we're just smokin' in here" (NTSB, 1997a, p. 4)

Reports such as this one and the CFIT accident at Arkansas indicate that when a rule is in the process of being infringed the use of imprecise language appears to facilitate the infringement in a way that would be difficult if a precise statement of the aircraft state was made. Furthermore the observation that imprecise language is a recurrent feature of SFP related occurrences suggests that such language may be interpreted as tacit approval from the other FCM(s).

7.2.5. RESULTS OF THE CONCORDANCING OF UNCLEAR COMMUNICATION RELATED TRANSCRIPTS

This section outlines the taxonomy of verbal communication for the three most recurrent types of SFP occurrences outlined in Chapter 7.2.1.

7.2.5.1. THE VERBAL CHARACTERISTICS OF "FLIGHT BELOW A SAFE ALTITUDE" OCCURRENCES

Accidents at Arkansas and Mount Erebus were both instances where the flight crew thought they were somewhere different from their actual position for a variety of reasons. In both these cases it was a precondition of the flight they were conducting that they maintain visual contact with the terrain. Given that they both crashed into the surface it is reasonable to conclude that they did not meet this precondition. Instances of attenuated communication in this situation centre upon knowing where the aircraft is and ensuring that the weather is good enough. Throughout this section a possible unhedged interpretation is shown in parenthesis.

EXPRESSIONS OF CONCERN RELATING TO WEATHER CONDITIONS

"*Doesn't look very promising, does it?"* (TAIC, 1979, p. 42) (I doubt that the weather is good enough for what you are intending to do)

The tag "*does it?"* invites the addressees to agree or disagree; in this case there was general agreement among the flight deck occupants that the weather was marginal.

"*Actually those conditions don't look very good at all – do they?*" (TAIC, 1979, p. 74) (The conditions do not appear suitable; what are you going to do?) The tag *"do they?"* invites a response. The following extract was used by an accident flight crew at Aspen:

"That's not good" (NTSB 2002, p. 4)

"That's not good" was also used by an accident flight crew at Traverse City, Michigan (NTSB, 2008b, p. 173) to describe a forty eight knot tailwind on final approach, which by any assessment is understated by the language used. All three extracts above use a linguistic device known as a *litote* which deploys understatement by stating that something is *not good* rather than saying that it is bad. Flight crews use litotes frequently.

"Dark cloud ahead" (KNKT, 2012, p. 31) (what are you planning to do about the weather ahead?)

According to Grice's maxim of quantity the comment above, from the Jakarta accident first officer, advising his captain that there is dark cloud ahead or that cloud is being flown through should not be necessary because it is visible to the addressee. In this case, flouting the maxim of quantity appears to be used as an appeal for action. Below is a similar extract from the Arkansas first officer:

"We're going in and out of some scud" (low cloud) (NTSB, 1974, p. 32)

In this extract the speaker states something that should be obvious to the addressee, seemingly in an attempt to prompt some corrective action. Support for this interpretation is found in the extract that immediately followed, in which he expressed his concern more directly:

"I sure wish I knew where the # we were" (Ibid., p. 32) (I don't know where we are)

The Gricean maxim of quantity emerges as a useful indicator of the expression of concern; if something obvious is being communicated it probably means the addressee should attempt to understand why the communication was considered necessary by the speaker. The comments below carry more force by emphasising that the assessment being offered relates to the here and now and implies that urgent action is needed.

"Here we are…we're not out of it" (Ibid., p. 35) (we descended to clear cloud and it hasn't worked…now what?)
"We're in solid (cloud) now" (Ibid., p. 34) (we should be in visual conditions)
"You're really a long time on instruments this time are you?" (TAIC, 1979, p .72) (You should not be flying in cloud for this long because we are close to high terrain)

EXPRESSIONS OF CONCERN RELATING TO TERRAIN CLEARANCE

Terrain clearance concerns were closely linked to concerns related to the weather. The reason that terrain clearance concerns are so highly mitigated in the transcripts is that whilst weather conditions are to some extent subjective, there are clear rules related to descent below a safe altitude. This means that a PF needs to tread carefully when stating their intention to descend in marginal conditions and a PM needs to be sure of their ground before implying that a rule is about to be infringed.

ATTENUATED EXPRESSION OF INTENTION TO DESCEND BY PF

In the three examples below, all from the Erebus accident, the speaker retains the right to assert that what was said was only a proposal, thereby avoiding face threat if anyone else were to disagree.

"I'll have to do an orbit here, I think" (TAIC, 1979, p. 51) (an orbit is a very uncommon manoeuvre; I'll see what my colleagues think before I do it)

"I'll do an orbit here to get down, I think" (Ibid., p. 54) (I'll do an orbit but if anyone seriously disagrees I can claim it was only a plan)

"We might have to pop down to fifteen hundred here I think" (Ibid., p. 71) (this is a very unusual manoeuvre in a large airliner, I'll use informal language to make it sound less unusual)

Notably, the speaker initially avoids saying he is going to do an orbit, just that he is thinking about it; then he explains why he thinks it is necessary. Later he uses informal language to describe a descent in the vicinity of high terrain. Only twenty seconds later, more direct expressions of concern were heard.

The extract below is from the Dulles accident and is an example of a category of accidents where the flight crew misunderstood the preconditions that need to be met in order to descend on final approach for landing.

"When he clears you that means you can descend…to your initial approach altitude" (NTSB, 1975b, p. 5) (I'm not really certain about this, so I'll phrase it as a statement and try to get the others involved and maybe we can resolve the ambiguity)

Given that all three FCMs entered this discussion it is likely that what appeared to be a statement of intent was presented by the speaker for the approval of the rest of the flight crew. Almost twenty years later the flight crew at Cali went through a similar verbal process and made the same error:

"OK so were cleared to five (thousand) now?" (Flight Safety Foundation, 1998, p. 9).

(We have been very busy for a few minutes and I'm not completely sure where we are in relation to the published procedure route. If I ask a direct question it reveals that I have temporarily lost situational awareness. If I pose the question as a statement it looks like I am just asking for confirmation of something I already know). Clearly both the comments in the extracts above were questions posing as statements so it is important to understand why this type of unclear communication is used. By making a statement such as "*OK so we're cleared to five now"* the speaker gives the impression that he knows the rules and is completely situationally aware. Endsley (1995) has described what superior situation awareness looks like, and for a pilot, knowing one's relation to the terrain clearance altitudes is an absolute requirement during a descent in proximity to high terrain. Similarly an admission that a captain is uncertain about how an instrument approach procedure should be flown carries strong potential for face threat so although the rational choice would be to ask the other FCMs their advice directly, it is likely to be avoided.

DESCENT BELOW MINIMUM HEIGHT ON AN APPROACH IN MARGINAL WEATHER

This category includes occurrences at Aspen (NTSB, 2002), Houston (NTSB, 2006b) and Zurich (SAIB, 2001). A detailed knowledge of the legislation is not necessary to understand the rules regarding the latter stages of an approach to land, where the FCMs transition from instrument flight to visual flight to perform a landing. The important point is that in the three accidents cited above there was a precondition that the flight crew should see the runway or its lighting at a specified height and if this was not achieved a missed approach was necessary. In none of these instances was an ability to see the ground a requirement or a justification to continue below the minimum height unless the runway or its lighting was visible. The extracts below relate to a flight crew who crashed an Avro Regional Jet at Zurich after flying below the minimum height without the necessary visual reference.

"*We have ground contact"* (SAIB, 2001, p. 19) (I can see the ground therefore the weather might be suitable for a landing).

"I have ground contact…we're continuing at the moment" (Ibid., p. 19) (I have decided to infringe a rule but I am only doing it for a moment; if you don't challenge me I will continue with the infringement).

"It appears we have ground contact…we're continuing on" (Ibid., p. 107) (I can see the ground and that is enough for me to continue towards the runway even though I do not have the necessary visual reference and I should be making a missed approach).

As previously stated, the comments about ground contact were irrelevant except that they may have signified in advance an intention to infringe the rules. *"We are continuing at the moment"* was probably intended to convey that there was some rationale behind this very dangerous procedure. The contention that a comment relating to ground contact could be an advance indication of rule infringement is supported by the transcript below from the Houston accident (NTSB, 2006b):

"…we're looking for two hundred and forty four on the altimeter and that'll give us two hundred or if we see anything....that'd be, what if I see ground contact, I'll just let you…I'll call it out". (ANN, 2005) (I am aware that the minimum altitude is two hundred and forty four feet but I will call it out if I see the ground and you might agree to continue even if we cannot see the runway lights).

In this extract the PM apparently seeks to gain approval from the PF to include ground contact as a criterion for continuing the approach in much the same way as the pilot at Zurich. It is clear from the transcript that this is how the PF interpreted this comment because he politely rejected it:

"I'll probably stay on the gauges all the way down" (ANN, 2005) (you can look at the ground; I'm looking at the instruments until I see the runway). The use of *probably* avoids a direct dismissal of the idea as such a rejection would be a threat to the first officer's positive face.

The Aspen accident also required that the runway or its lights be visible. According to the report, when the aircraft was 200 feet below the minimum height the captain asked the first officer:

…whether he could see the highway, and he replied, about one second later, "I see the high-way" (NTSB, 2002, p. 7) (If you can see the highway I intend to continue despite the fact I do not have the necessary visual reference and I shouldn't be this low in the first place).
It should be emphasised that seeing the highway was not a required criterion whereas seeing the runway was.

EXPRESSION OF UNCERTAINTY OF LATERAL POSITION

"I'm just thinking of any high ground in the area that's all" (TAIC, 1979, p. 70) (I don't want to be seen to be challenging your authority but I am uncomfortable with our terrain clearance).

"If we keep this up indefinitely we'll be in Tulsa" (NTSB, 1974, p. 31) (we are a long way off course and I am concerned that neither of us knows our position accurately).

"I sure wish I knew where we were" (Ibid., p. 32) (I don't know where we are).

"I wish I knew where we were so we'd have some idea of the general terrain around this place" (Ibid., p. 35) (I don't know where we are and I don't think you do either; I am concerned about our terrain clearance).

To ATC: *"I can almost see up the canyon from here but I don't know the terrain well enough or I'd take the visual"* (NTSB, 2002, p. 36) (I do not have sufficient knowledge of the terrain, can you (ATC) offer me some assistance?).

"I can't even get Texarkana any more" (NTSB, 1974, p. 33) (we must be a long way off course because I cannot receive a radio beacon that should be in range).

"Well we must be somewhere in Oklahoma" (Ibid., p. 34) (we only know our position at the most imprecise level).

"Where we headed?" (Flight Safety Foundation, 1998, p. 11) (We are not going where we need to go).

"Keep on trucking" (NTSB, 1974, p. 34) (I don't have a clear plan, just keep doing what you are doing while I think).

"Let's press on" (Flight Safety Foundation, 1998, p. 11) (I have no plan; I am trying to re-gain situational awareness).

"The hold's there isn't it?" (UK AIB, 1981) (I need someone to confirm my understanding of the direction of this holding pattern).

Uncertainty of lateral position was expressed by appeals, usually from subordinate FCMs. In the Arkansas accident the co-pilot made at least ten indirect appeals for the captain to explain how he was navigating and where they were; these were usually prefixed by *I wish I knew* or by a statement that highlighted the imprecise nature of the navigation being undertaken. Only near the end of the ill-fated flight did he challenge the captain directly and even then the captain did not take corrective action. The captain generally responded with vague and dismissive comments rather than using the precision required of the situation. He referred to a

3000 foot mountain as a hill. There was a repetitive tendency to press on despite not knowing where the aircraft was; this was particularly evident at Cali *("let's press on")* and Arkansas *("keep on trucking")*. The Tenerife transcript included five comments with the tag *isn't it?* Whenever the Arkansas captain provided position information he communicated it in such a way that it was largely incomprehensible to his addressee. In the Cali and Arkansas transcripts the comment *we # up* (expletive) was used; in both these cases if corrective action had been taken at the point that red line had been acknowledged there would have been no accident.

EXPRESSION OF UNCERTAINTY OF VERTICAL POSITION

The extract below is from the Dulles CFIT accident where the flight crew misinterpreted the approach chart.

"According to this dumb sheet (referring to the instrument approach chart) it says thirty four hundred to Round Hill is our minimum altitude." (NTSB, 1975b, p. 5) (I do not understand this chart).

In the following extract the Arkansas captain plucks a figure out of his head in response to concerns about the terrain from the first officer:

"The highest point out here is about 1200 feet" (NTSB, 1974, p. 36) (I don't know the terrain elevation accurately so I'll state a value that supports the actions I am currently taking).

"You can quit worrying about the mountains because that'll clear everything over there" (Ibid., p. 30) (I am tired of you questioning the terrain clearance).

The Dulles flight engineer expressed doubt about the vertical profile that was being flown:

"We're out here quite a ways" (NTSB, 1975b, p. 4) (It looks like we are quite low considering how far from the airport we are).

The first extract above is a clear case of speaker attributing his misunderstanding of the procedure to the *dumb sheet.* The use of *about 1200 feet* in the second extract is an inappropriately vague way of expressing terrain clearance, which usually requires specific margins above the terrain that are difficult for a pilot to derive. Flight crews are required to comply with specified minimum altitudes, not derive them themselves. The level of imprecision in the third extract suggests that the speaker did not know either the aircraft's exact position or the elevation of the terrain. The last comment evaded the investigators but it appears that the flight engineer was commenting that the flight crew were flying lower than they needed to be at their current distance from the airport; the aircraft crashed 25 miles short of the runway. The chart that the pilot described as dumb depicted a far more rational descent profile than the very shallow one that resulted in the crash.

7.2.5.2 THE VERBAL CHARACTERISTICS OF "LOSS OF CONTROL OCCURRENCES"

This section examines a specific category of loss of control (LOC) accident namely those which occur just after takeoff. This category is also relevant to accidents that occur during a missed approach. Although there are other types of LOC accidents, due to a number of recent occurrences this type of accident is attracting the aviation community's scrutiny as this study is underway in 2016.

UNCLEAR LANGUAGE CHARACTERISTIC OF "LOSS OF CONTROL AFTER TAKEOFF OCCURRENCES"

Loss of control (LOC) after takeoff is a disturbing recurrent phenomenon in which fully serviceable aircraft crash in an extreme attitude, usually within a very few minutes of taking off. The accident literature indicates that even minor distraction can trigger such an accident.

Although this research could find no instance where failed communication was cited as a cause of LOC, it is usually there in the background. The literature indicates that this type of accident is characterised by deficiencies in communication between the FCMs. Some of the communication was not explicit enough, some was misleading and in all the instances outlined in this section, the communication was too late. Although this section examines three occurrences involving Boeing 737 aircraft there are similar occurrences involving other types. Examining accidents involving one type of aircraft confers an advantage by reducing the influence of confounding features of different aircraft systems and procedures. Also the three occurrences involved pilots of three different airlines, indicating that the ideas suggested here may be generalizable. The three accidents are:

- Ethiopian Airlines flight 409 near Beirut, Lebanon. 25th January 2010. Airborne 4 minutes (Republic of Lebanon, 2012)

- Flash Airlines flight 604 near Sharm el Sheikh, Egypt. 3rd January 2004: Airborne 2 minutes 30 seconds. (Egyptian Ministry of Civil Aviation, 2004)

- Kenya Airlines flight 507 near Douala, Cameroon. 5th May 2007: Airborne 1 minute 33 seconds. (Republic of Cameroon (2007)

The manual concordancing found that in the approximately eight minutes of flight conducted by the three accident flight crews all made non-routine reference to the autopilot. The Flash Airlines pilots referred to the autopilot eight times in their short flight. References to headings and directions were the next most recurrent type of communication. The Flash Airlines flight crew used the term left or right seven times. The Kenyan first officer miscommunicated the direction of turn once and corrected himself twice in the same communication. In each case there was miscommunication or absence of communication regarding the autopilot status.

In each of these accidents the aircraft gradually exceeded the normal maximum bank angle of 30˚ before the PF attempted corrective action. In the Flash Airlines accident it is likely that the failure to successfully engage the autopilot precipitated the events that followed. It is possible that at least one of the PFs in these three accidents simply forgot that he had been unsuccessful in engaging the autopilot and thought that it was flying the aircraft. In the Flash Airlines accident the first indication of a problem was when the PM called *turning right* when the intended direction of turn was left. The call *turning right* made in response to the captain's incorrect direction of turn was ambiguous because simply saying *turning right* can have more than one meaning. In a LOC accident involving a Saab 340 commuter airliner at Nassenwil, Switzerland (SAIB, 2004) the controller noticed that the aircraft was turning right instead of left after takeoff, which prompted the comment *"Crossair 498 confirm you are turning left"* (Ibid., p. 13) despite the controller knowing that the aircraft was turning right. So in the Nassenwil case, the use of *turning left* was an attenuated warning that the aircraft was not turning left, probably enacted in this way to avoid directly pointing out the flight crew's error. Although the Saab subsequently crashed, it was probably also the controller's intention to avoid any further confusion to the flight crew which prompted him to clear them to continue turning the wrong way. The comment "*turning right"* made by the Flash Airlines' PM at Sharm el Sheikh was intended to convey precisely the opposite to the Nassenwil instance so it is understandable how such an attenuated comment could be misinterpreted. The first officer's attempt at Sharm el Sheikh to avoid explicitly stating a mistake was being made by the captain probably resulted in a delay during which time the bank angle was allowed to increase. Given that the first response to the comment *turning right* resulted in an exclamation of "*what?"* and a concurrent increase in bank angle it is reasonable to speculate that the captain may have interpreted it as being an instruction. The first officer subsequently elaborated by saying "*aircraft is turning right"* to which the captain says "*ah, turning right"* indicating that he had understood what was trying to be conveyed. The accident report commented that the subsequent *overbank* callout was "not directive", presumably meaning that a direct order to turn left should have been issued. In all three instances the PFs' first response to the warning was to increase the bank angle. Although this is a small sample, this is a rare phenomenon in which all the pilots involved reacted in the same fashion. It may be that a more explicit aural instruction would have been reacted to more effectively. In each of the accidents there was a suggestion that either the bank angle warning or the stick shaker was not immediately recognised; in any case none of the pilots initiated a stall recovery. The contextual-cueing strand of this research provides some explanations for incorrect responses to warnings and alerts that are rarely experienced by flight crews. Another common feature of all three accidents was a lack of awareness of whether the autopilot was engaged or not. It is likely that at some stage in each of these accidents the PF erroneously believed that the autopilot was flying the aircraft. In fact at some stage in each accident each PF called for the autopilot to be engaged and the request was not complied with; furthermore, none of the PMs communicated that fact to the PF. It could be that the request was not carried out due to the PM's workload state; this would help to explain why in one case the PM explicitly stated that he had engaged it. The Sharm el Sheikh report suggested that the PM may have simply assumed the autopilot had engaged because he had pressed the button. The underpinnings of cognitive errors related to misattributions involving system status are examined in more detail in the contextual-cueing strand of this research. Another possibility is that these PMs decided that the timing of autopilot engagement was inappropriate. Failure to communicate may have been a consequence of AAC, the phenomenon where all the communicative options open to a speaker are ones which would normally be avoided. Each of these PFs requested autopilot engagement at a stage when the aircraft was already in an extreme attitude that the autopilot is not designed to rectify so the PM would probably not want to comply with that command. On the other hand, it was probably also evident that the reason it was being requested was in a desperate attempt to try and regain control of the aircraft. This is exactly the scenario that Bavelas (1985) has observed can result in complete withdrawal from communication. The overarching observation relating to LOC just after takeoff is that communication often does not occur, and when it does, it is not timely or explicit enough. In all of these cases the PM should have taken control, in which case it is likely that the accident would have been averted. After an extensive review of LOC accidents no instances could be found of either a captain successfully taking over from a first officer or vice versa; this behaviour is likely to be to some extent grounded in both positive and negative-face threat avoidance. It is a recurrent dilemma for subordinate FCMs knowing how far to allow a situation to develop before speaking up. A captain turning the wrong way or any other LOC instance is likely to be a one off event that most FCMs have never encountered before. There is almost certain to be a short period during which the PM confirms that they are not making a mistake themselves because to distract a captain unnecessarily at a critical phase of flight could aggravate the situation and would involve face threat for both parties. The most effective means of communicating such an error would be to use a bald-on-record statement such as *you're turning the wrong way…turn left now* but these are very face threatening and were almost completely absent from the transcripts reviewed for this section. Although by coincidence these three examples involved a PF who was a captain and a PM who was a fairly junior co-pilot, it should not be inferred that a similar reluctance to communicate and intervene is less likely when the roles are reversed. In the Cali accident cited earlier, the aircraft was flown by the first officer and the captain failed to intervene even when he was issuing quite forceful commands such as *turn right…right now* (Flight Safety Foundation, 1998, p. 13) and even left the first officer flying during the incorrectly flown terrain avoidance manoeuvre.

7.2.5.3. VERBAL CHARACTERISTICS OF OCCURRENCES INVOLVING OMISSIONS OR INAPPROPRIATE FLIGHT CREW ACTIONS

THE CAPTAIN WHO IS NOT LISTENING

The concordancing of this category of occurrence was based upon accidents at Portland (NTSB, 1979) and Guantanamo Bay (NTSB, 1994a). As the Portland accident was a fuel starvation occurrence the word *fuel* was searched. In the eighteen minutes before the accident fuel was mentioned by the first officer and engineer with increasing urgency no fewer than five times. Only once was this acknowledged by the captain and no attempt to get him to engage with the topic was evident. At Guantanamo Bay although the outcome was a LOC accident the problems started much earlier with a reluctance to explicitly question the captain's decision to make a difficult approach when a comparatively straightforward one was available. Because the category "omissions and inappropriate flight crew actions" could encompass many different types of occurrence, concordancing was found to be ineffective. It was however, possible to identify recurrent themes that accompanied situations where FCMs were uncomfortable about a course of action being taken. The reports indicated that usually the captain was PF in such cases. The Portland and Guantanamo Bay accidents both featured a captain who had a clear idea of how they were going to conduct the flight and although the other FCMs expressed uncertainty about what was being proposed they probably felt they did not have the authority to disagree because nothing being proposed would have violated a rule. Both first officers expressed their doubt about the successful outcome of what was proposed but neither obtained a response from their captain. The Guantanamo Bay captain decided that he would fly the more difficult approach "*just for the heck of it*" (NTSB, 1994, p. 100). The first officer's reply "*okay*" could mean many things, from a simple acknowledgement that the intention had been heard, to wholehearted agreement. Given that no discussion had taken place and that the rationale given for conducting the more difficult approach was not very professional it is likely that it was used in the fashion suggested by Gravano et al. (2009) to convey a "satisfactory" assessment rather than enthusiastic agreement with the proposed course of action. His subsequent communication of the proposed landing to ATC expressed tentativeness about its likelihood of success:

"We request to land to the east…if we need to we'll make another approach…but we'd like to make the first approach to the east"… (Ibid., p. 100)

The flight engineer also quipped:

"Just don't do no rolls on finals" (Ibid., p. 104)

Although these might seem insignificant remarks they all signal that the approach carried risks that the individual FCMs recognised but at no time discussed in direct language. It was noticeable that in both transcripts the first officer and flight engineer provided detailed critique of the deteriorating situation but never directly challenged their captain's course of action. The main characteristic of these transcripts was that they included information that should not have been necessary to convey if the flight was being conducted satisfactorily.

With the benefit of hindsight it is obvious that the captain at Portland lost awareness of the fuel state very early on. The captain at Guantanamo Bay was attempting to do something that was difficult and, as it transpired, beyond his capabilities. It is very uncommon for instructions on how to fly the aircraft to come from subordinate FCMs so this might be the most obvious verbal marker that something is amiss. There follows several of the comments made by the Guantanamo Bay first officer and flight engineer with an interpretation of what was probably intended to be communicated in parenthesis:

"You wanna get dirty and slowed down and everything?" (NTSB, 1974, p. 117) (I think you should have the landing gear and flaps extended by now).

"That's the end of the runway right there....I'd give myself plenty of time to get straight" (Ibid., p. 117) (you're getting too close to make a safe turn to the runway).

"I think you're getting in close before you start your turn" (Ibid., p. 118) (I'm concerned that this is not going to work out).

"The runway is right there…you're right on it" (Ibid., p. 118) (we're way too close).

Captain: "Going to really have to honk it…let's get the gear down" (Ibid., p. 118) (I have recognised that I am far too close and I should have configured the gear and flaps earlier; I am going to continue with this dangerous approach).

*"Slow airspeed" (*Ibid., p. 121) (you are in danger of stalling).

"Check the turn" (Ibid., p. 121) (you are overbanking).

"Do you think you're gonna make this?" (Ibid., p. 123) (I don't think you are going to make this).

Five hundred…you're in good shape (Ibid., p. 123) (you don't meet any of the criteria for a stable approach but you might achieve a successful landing…you're continuing anyway so I had best support you).

In an accident at Islamabad (PCAA, 2010) the first officer made a prolonged attempt to dissuade his captain from flying into terrain but was still unsuccessful. The problem with both the Islamabad (PCAA, 2010) and Guantanamo supporting FCMs is that they didn't communicate their disagreement with the course of action proposed by the PF early enough and therefore were implicated in its execution. What is meant here is that at Islamabad it is inconceivable that the first officer did not know that his captain was intending to infringe a rule; after all he (the first officer) could see the unofficial route in the aircraft's flight management computer. Once tacit approval has been given it is difficult to subsequently fail to support that action. There was no dissent whatsoever from the first officer as the aircraft was deviated from its cleared route. When the first officer was asked by air traffic control whether they were visual with the airfield he was in a bind:

ATC: *Are you visual with the airfield?* (PCAA, 2010, p. 24) (I cannot see you so I don't think you can see the airfield).

F/O to Captain: *What should I tell him sir?* (Ibid., p. 24) (I don't think you can see the airfield; do you want me to lie?).

This indicated that the airfield was not in sight but it was possible to report that the ground was visible although this was not a required criterion for continuance of the approach being flown. The first officer told his captain to <u>*pull up*</u> several times in the minute before impact but by this time he (the captain) was spatially disoriented and his performance was seriously degraded (See the spatial awareness strand of this research). Given that the first officer was situationally aware (he knew where the terrain was and he knew they were too low) he could have taken over and recovered the situation; this however, would be very face-threatening. It was noticeable in the Islamabad (PCAA, 2010) CVR transcript that the first officer addressed his captain using the prefix "sir" even in the seconds before impact. This contrasted starkly with the Guantanamo CVR transcript where informality was far more evident. Hofstede's power distance index (2011) measures the extent to which the less powerful members of organizations or cultures accept that power is distributed unequally. Although there is insufficient data in the transcripts to comment upon either the operators' culture or the culture of Pakistan or the USA it can be said that both countries occupy the mid ranks as of 2016, with Pakistan rated at 55 and the USA at 40. This means that a first officer should not feel excessively inhibited expressing an opinion in either of those cultures. Research by Fischer & Orasanu (1999) involving US airline pilots found that captains generally preferred to use commands while first officers predominantly used hints. Both captains and first officers favoured communications that appealed to the crew concept rather than to any particular status based model, a finding supported in the Guantanamo Bay transcript but less evident in the Islamabad transcript. They also found that as risk increased, captains became more direct in their communications whereas first officers quadrupled their use of attenuated obligation statements. The debate over whether the hierarchical structure of a military background or the characteristics of certain cultures inhibit clear communication is one that was initiated by an accidents involving Korean flight crews in Guam in 1997 (NTSB, 2000 pp. 147-8) and Stansted in 1999 (UK AAIB, 2003, p. 50) and has been reignited by a Korean Boeing 777 crash at San Francisco in 2013 (NTSB, 2014a). There is a persistent but largely unspoken narrative suggesting certain cultures are less able to express criticism of a hierarchical superior than others but it would be a mistake to differentiate excessively along cultural lines. Although at Islamabad the first officer was criticised for being a "passive bystander" (PCAA, 2010, p. 32) it is hard to criticise the strength with which he challenged his captain verbally; his captain was just not listening. In fact there are examples from almost every culture, of unfathomable failures in communication sometimes involving pilots of very high calibre. The first officer in the Cali accident had been *instructor of the year* for the entire US Air Force prior to joining American Airlines and the Russian test pilot at Jakarta was the most experienced pilot on that aircraft in the world. This suggests that no cultural background is immune from the risks of failed communication.

THE COLLEAGUE WHO NEEDS SOME SUPPORT

There were two clear instances in the transcripts of an under confident captain who was paired with a first officer whose actions appeared to be targeted at offering more than usual support. In the Detroit accident report (NTSB, 1991b, p. 53) it was hypothesised that a role reversal may have taken place in which the first officer had effectively assumed the role of captain. Although not mentioned in the Chicago report (NTSB, 2007b), there was some evidence of persuasion from the first officer and there was quite clear evidence that the captain interpreted it that way. Although two transcripts represent a small sample, a few common characteristics were evident in the reports; firstly, the first officers both had extensive previous experience as a captain. Secondly, they both presented as very confident. However, the most influential aspect of their verbal behaviour was that they both gave an impression that they were more knowledgeable than they actually were. At Detroit this narrative centred upon the first officer's distinguished military career whereas at Chicago the narrative was almost exclusively related to the first officer's knowledge about how effective the autobrake system was, despite the fact that he had never witnessed it operating either in an aircraft or a simulator. Nothing he said was untrue but it could have given the impression he knew more than he actually did. Both first officers offered unsolicited instruction to their captain at some time during their respective transcripts. The first officer at Detroit was found to have embellished both his military record and his degree of familiarity with the taxiing operation just about to be undertaken. How this is related to attenuated communication is that once a speaker has set himself up as an authority he has a long way to fall if circumstances indicate that he is not quite the authority he projected. At Detroit this had catastrophic consequences when the seemingly knowledgeable first officer became hopelessly lost whilst assisting his captain to taxi in fog. On three separate occasions he ignored the captain's request that he advise ATC that they were unsure of their position; had he done this it is likely that the accident could have been averted. This is a further instance of an AAC bind along the following lines: admit I am lost versus cause an accident. For most of us that would be an easy choice but human behaviour is complex and this is not an isolated case of a pilot refusing to ask for help in the interests of face threat avoidance.

THE ROLE OF RESPONSIBILITY AND ACCOUNTABILITY

As far as is known, this construct has not been examined before; it refers to situations where a speaker is aware that something is wrong but either communicates the fact in attenuated form or directly understates the seriousness of the situation. The former case was evident in a serious occurrence at St Kitts (UK AAIB, 2010a) and the latter at Houston (NTSB, 2006b); in both cases the influence of accountability or responsibility appears to be relevant. At St Kitts an air traffic controller knowingly allowed a British Airways Boeing 777 flight crew to start their takeoff from a position on the runway that they had not intended. The controller had asked the pilots whether they were happy to depart from a given position but their reply clearly indicated that they were making a mistake regarding their location on the runway. The controller did not challenge this inconsistency and the aircraft departed from half way along the runway. Although it was outside the remit of the associated report to comment upon the reasons why the controller took this action it can reasonably be speculated that he believed that once he had advised the flight crew, his responsibility had been discharged. If this is how those who support flight crews view their responsibilities it demonstrates a lack of connection within the aviation safety system. The second way that responsibility and accountability can influence flight safety is when someone makes an error that impacts safety and then attempts to downplay its significance. It is intuitively understandable how a team member who makes a mistake is likely to feel accountable for that error; the problem occurs when that individual then uses language that downplays the seriousness of the situation that has resulted. This completely original construct was prompted by an accident in which a very experienced flight crew (effectively two captains) were flying into Houston in bad weather. The PM made an incorrect selection of navigation aids at a late stage in the approach, which meant the PF lost some of his navigation displays and resulted in an unstable approach, which should have prompted a missed approach. The PM repeatedly misrepresented the seriousness of the situation by encouraging the PF that the approach should be continued; the aircraft crashed short of the runway. Although it may seem a weak explanation to the uninitiated, the motivation for an experienced FCM to avoid making a missed approach for which he is accountable is likely to be much stronger than, for instance, if the missed approach was due to a factor for which he was not accountable, such as the weather. This behaviour is likely to be underpinned by the face-wants of the individual concerned. Making an incompetent error is unlikely to match one's own desired self-concept or to be an image that one wants to present to others. Negative-face threat may also explain why in this and other instances the other FCM accedes to the wishes of the speaker. This phenomenon was evident at Cali where the captain, who was PM, incorrectly programmed the navigation computer to fly in a completely different direction to the intended route (See Figure 8.4). Less than one minute before impacting a mountain the captain said *OK you're in good shape now,* which was an extreme underrepresentation of the seriousness of the situation. Because relevant instances are few, it is difficult to locate evidence to support the contention that for some pilots concealing an error assumes a greater importance than rectifying it. An accident at Charleston in which the captain omitted to check the flap setting before taxiing but noticed his error at high speed during the takeoff, resulting in an almost catastrophic overrun when he rejected the takeoff at high speed. Although it is not necessary to understand the details of what is said in the telephone call the captain made just minutes after the accident it is relevant that he omits to mention that the warnings were caused by his actions.

… "*well we're going down the runway here in uh Charleston, West Virginia, and we got a config flap config uh spoiler and I rejected and uh well long story short um past the runway I'm into that over thing you know where the airplane sinks into the…"*

(NTSB, 2010c, p. 12 28)

This tendency to use language that downplays personal responsibility is not restricted to pilots; at Sochi an Airbus flight crew was making an approach and had been given clearance to land. At a late stage of the approach the flight crew was ordered to discontinue the approach. To be ordered to discontinue an approach after having been cleared to land is very unusual and it is certain that the controller would have known this. Instead of ordering the flight crew to go around, the controller described the individual components of a missed approach by requesting a climb and a turn. This was clearly an attenuated description of a go around. As the aircraft was of French manufacture the French BEA contributed to the Russian report. The French BEA was critical of the way the instructions relating to the missed approach were communicated to the flight crew.

"…when the controller aborted the final approach, he gave a series of instructions that appear to be piloting instructions rather than a clear instruction for a missed approach. In doing this, the controller transformed himself into a decision maker for airplane manoeuvring and it should be noted that, in fact, the pilot performs the instructions received

in a sequential manner”. (Interstate Aviation Committee Air Accident Investigation Commission, 2006)

The pilot carried out the instructions received in succession, but did not appear to have immediately adopted the missed approach procedure. The flight crew became confused by this less clearly-defined procedure and flew this completely serviceable aircraft into the Black Sea. Whilst the confusion that was caused by the specifics of how the instruction was communicated is not in question, the underlying reasons for the controller’s departure from conventional aviation language are a matter for debate and argument. There is little doubt that requesting a climb and a turn sounds like something less serious than a go around to a pilot, and this may hold the clue. In such cases, if an actor considers that they may share some responsibility for an adverse situation such as a late go around they may be motivated to make it sound less serious than it actually is. As was stated earlier, no previous examination of this phenomenon could be found but now that it has been operationalised in this research it is likely that its effect will be recognisable in future occurrences.

7.2.6 THE LIMITATIONS OF THE VERBAL STRAND RESEARCH

Because no previous research into the causes of NPCs could be located, it was necessary to start the research with a blank sheet. The orientation towards impression management (IM) was logical to this researcher but it is conceivable that other research orientations exist. Nonetheless, it would be difficult to dismiss IM as an influence given the findings in this research. However, this was a preliminary examination of the phenomenon and a stated aim of the SFP construct is to be a repository for knowledge as it accumulates, so consideration of alternative views will be an essential part of that process in the future. Although the number of participants was low, there is no evidence that the responses would have been different with a larger research population. It could be argued that the *normal friendliness* and *crew cohesion* dimensions were quite loosely defined, but they were identifiable to the pilots who participated so they are likely to provide useful knowledge to both pilots and those who support them. There was a concern related to socially desirable responding which could have been addressed more fully if the responses had been confidential. Experts in critical discourse analysis (CDA) might criticise the research for lack of scientific rigour but it was made clear at the outset that this was not a formal CDA study, although such a study is conceivable. Certain limitations were imposed by being a lone researcher; for instance in thematic analysis it is desirable to have more than one assessor when developing the themes that will be used. The problem here was that there are very few individuals who possess both the technical and psychosocial knowledge to assist in this respect. The unclear communications section was a synthesis of peer-reviewed research and subjective opinion. It is difficult to envisage how this could have been avoided given some of the jargon in the transcripts. Different researchers could have reached different conclusions about what a particular speech act was intended to convey but it is unlikely they could validate their assessment any more fully than the assessments proposed in this study. So although there is considerable amount of informed opinion expressed relating to the unclear communication in the transcripts it is difficult to refute what is presented. Despite these limitations the verbal strand researched phenomena that have been identified in the current literature as relevant to aviation safety. The SFP construct is dynamic and any limitations evident in this research are likely to stimulate critique and contribute to the development of the ideas expressed in this thesis.

CHAPTER 8

THE SPATIAL AWARENESS STRAND RESEARCH AND EXPERIMENTS

This chapter describes some of the cognitive limitations that might contribute to the loss of positional awareness and consequential SFP evident in the occurrence literature. Although this strand may appear very dissimilar to the verbal strand, the flight crew at Lexington (NTSB, 2007a) who broke the sterile cockpit rule before an unsuccessful attempted take off had lost heading awareness whilst taxiing so the two factors are intertwined.

8.1 THE EFFECT OF ENFORCED ORIENTATION CHANGE ON COGNITIVE LOAD IN FLIGHT CREW

8.1.1 INTRODUCTION

Flight crews navigating the immediate airport environment whether inflight or on the ground usually utilise observer-centred navigation displays (NDs). However, on some occasions there is a requirement for flight crews to reorient at short notice to a different reference frame, usually a chart or electronic display, invariably aligned with north. It is highly likely that the flight crew at Lexington (NTSB, 2007a) were using such a chart to taxi to the run-way. The two experiments described here examined the extent to which transition between the observer centred (egocentric) and geographic oriented (allocentric) frames of reference invokes cognitive effort. Research conducted by Mousavi et al. (1995) and Frick (1984) has demonstrated that during integration of multiple sources of information from a single modality, considerable deficits in working memory capacity result. In plain language this means that a task such as reorienting from an egocentrically oriented map display (or the outside world) to a chart, both of which require visual attention, is likely to result in challenges to working memory capacity. Evidence supporting a link between working memory deficit and impaired decision making comes from both neuroscientific research (Bechara et al., 1998) and experimentally when working memory is placed under extreme time constraints (Hinson et al., 2003). Given the link between cognitive load, working-memory deficit and impaired decision making just outlined, if it can be demonstrated that flight crew cognitive load is increased during reorientation from egocentric orientation to another frame of reference, such reorientation may be implicated in a range of SFP related behaviours that have preceded a safety occurrence. The two experiments outlined in this section used context appropriate stimuli to measure cognitive load as a reorientation from egocentric to allocentric reference frame was performed. Experiment one measured pilots' response times (RTs) as they identified depicted runway directions of varying angular disparity from north. In experiment two, participants identified the location of a feature relative to a runway depicted on a northerly oriented chart from a range of orientations. The task required participants to adopt viewing perspectives of varying angular disparities from north. In combination, these two experiments addressed the most essential components of positional awareness: knowing where one is located, knowing where one is heading and knowing where significant features of the spatial environment are located. Previous research by Darken & Peterson (2001) suggests that when using a map for navigation most people seek to identify their location on the map and their orientation as a precursor to navigation. Pilots are likely to adopt a similar process when they need to use a map but they may experience the disadvantage of having previously been oriented to an observer oriented map display that obviated the need to know their precise location and orientation. It is the process of adaptation between the observer oriented (egocentric) display and the orientation of the chart (usually oriented north up) that is the subject of this research. Figure 8.1 illustrates the difference between allocentric and egocentric orientations using a simulation of an aircraft on final approach, its ND and a chart depicting the same scene.

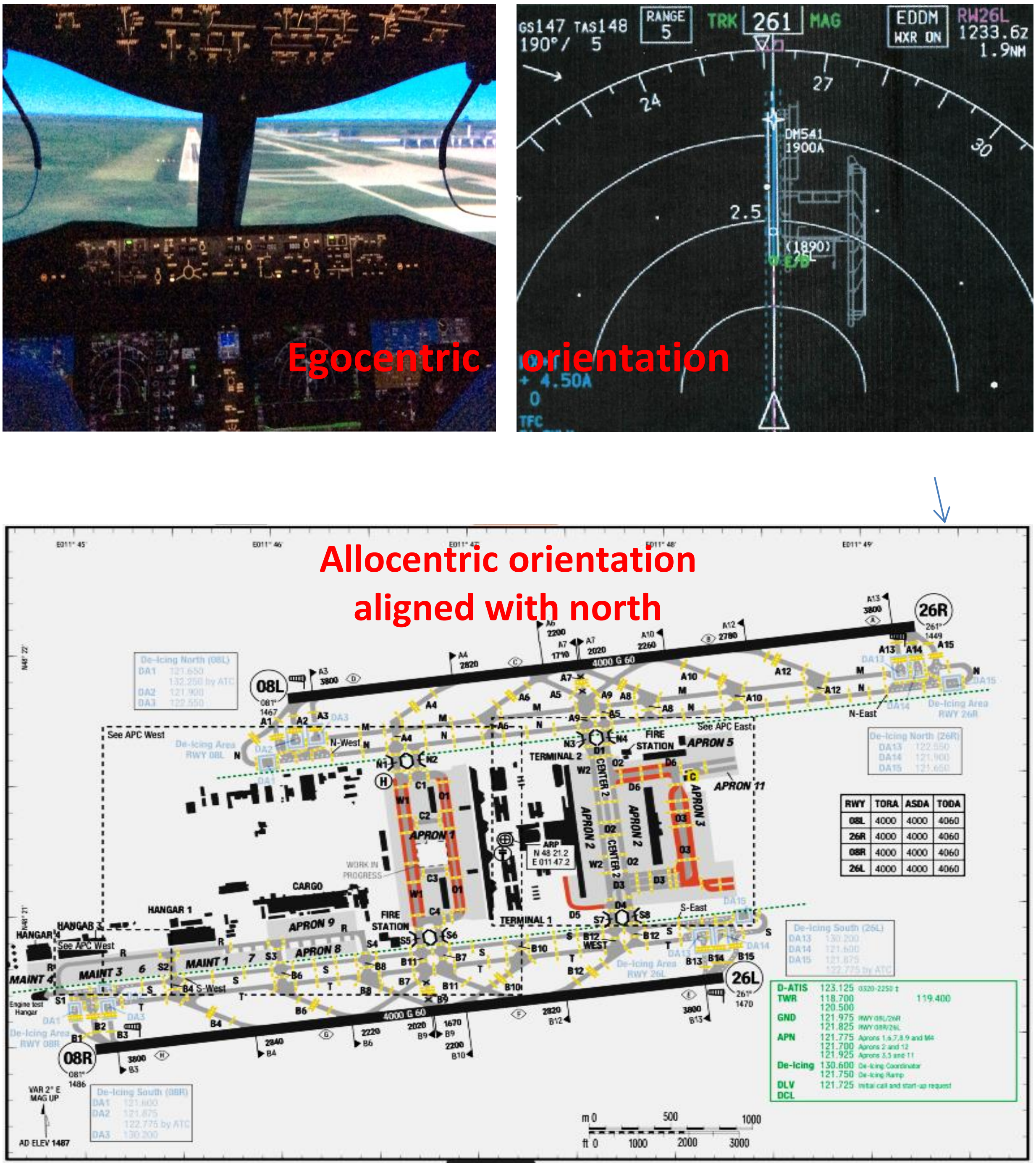


Figure 8.1: Egocentric and allocentric representations of the same scene.

The premise of this section of the research is that during readjustment from an egocentric display such as that found on most airliners, to a map oriented with north there will be a period when working memory may be occupied to the extent that other important tasks become degraded resulting in SFP. Accidents at Comoros, Cali and several others have been characterised by substandard performance from a pilot whose situation required a prompt transition from an electronic egocentrically-oriented navigation display (ND) to features on a chart oriented with north. The outcome of both of the aforementioned accidents was a loss of control followed by a crash into the surface. It is important to emphasise that there was nothing in these flight crews' histories to suggest that they were prone to lose control of the aircraft, so their substandard performance was probably the result of some aspect of their situational context. There is considerable empirical evidence in the literature to link loss of control occurrences with complex unexpected navigation challenges that have required basic skills such as using a chart or imagining a future flight path significantly different from that expected. It is not being suggested that pilots are unable to make such reorientations; intuitively they should be better than the general population at such a task. However, it is possible that they may be de-skilled at using a map because it is only required on rare occasions. Ironically, the pilots at Cali only needed to use a map when they incorrectly programmed their flight management computer after an unexpected runway change, which meant their workload was already subject to two factors (a change of route and of runway) that, according to ASRS reports [xii] increase pilots' workload. Since the accident at Cali, technology has improved and today it is less likely that a flight crew whose cognitive load has redlined while trying to become oriented would fly into a mountain as the Cali flight crew did but there is no room for complacency because in 2012 a Russian flight crew flying the most sophisticated airliner available at the time, lost track of where their aircraft was heading and crashed into a mountain near Jakarta whilst trying to mentally calculate the reciprocal track to their point of departure (KNKT, 2012, p. 33). At Comoros the flight crew were flying a complicated circling approach which many pilots would acknowledge is among the most demanding type of approach to fly in a large airliner. Furthermore the approach in question relied upon an egocentrically oriented map display for the initial phase of the approach (until the airport was acquired visually) but an almost 180˚ mental reorientation to visualise important features required for the landing (Union des Comores, 2013). Circling approaches undoubtedly come with inherent risks but flying is a risk laden activity; it is however, important that the risks are fully understood not just by pilots but by those who design and implement procedures. Although circling approaches are gradually being superseded by approaches based upon GPS it is likely that some of the most complex and potentially hazardous airports will retain circling approaches for the foreseeable future. This research examined and highlighted a cognitive limitation that, as far as is known, has not previously been considered a contributory factor in aviation safety occurrences.

8.1.2 REORIENTATION AND PILOT WORKLOAD: EVIDENCE OF A PROBLEM

Although the flight crews of modern airliners usually navigate using an observer centred ND, on occasions they also need to be able to navigate using charts which traditionally favour viewing in a north up orientation. Furthermore, state of the art electronic flight bag (EFB) applications such as those fitted to the Boeing 787 permit only limited orientation of the navigation chart resulting in a requirement for the user to mentally reorient during chart based navigation. For the purposes of this study the term <u>enforced change of orientation</u> refers to the action of transitioning from the information depicted on the electronic ND and the actual spatial environment, to depictions on a chart or EFB application presented in a north up orientation. The fact that this research could locate no instances where this phenomenon had been cited as a contributory factor in a safety occurrence does not detract from its relevance but indicates that it is probably a human factor that has been overlooked, possibly due to a belief that the risk has been mitigated by observer oriented displays. Whilst the accident at

Cali is the only definitive example of a disoriented flight crew using a chart (the CVR recorded the rustling of pages), the Comoros accident flight crew faced a particularly challenging approach in which they would need to align with the runway without all of the lighting the approach would normally require. It is highly likely that a chart would be needed in order to achieve this successfully. At Jakarta the flight crew were unable for some time to decide what heading they needed to fly and eventually just decided to fly the approximate reciprocal of their previous track; such a determination would almost certainly have involved chart usage. At Islamabad it was clear that once the aircraft deviated from the route the pilot was expecting he had very little awareness of what his heading was; it took just under three minutes for control to be lost. This research hypothesises that the sudden decrease in flight crew performance may be related to the cognitive load invoked during the transition from the routine and relatively simple egocentrically oriented navigation of the ND to the more complex navigation based upon the north-up oriented chart. It is noteworthy that some of the most complex circling approaches require a comprehensive understanding of features that are often not visible on the ND, as was the case at Islamabad, where the pilots were avoiding a restricted area only depicted on charts. A particular challenge for this research was the potential for the rapid rate of technological advances to reduce the relevance of this research, which it is acknowledged challenges some of the safety related mitigations afforded by such advances. In defence of this research, recent occurrences involving FCMs flying state of the art airliners indicates that there will be an ongoing requirement to understand the processes involved in integrating egocentric information from the aircraft's instrumentation with features shown on a chart, particularly during unexpected route changes, circling approaches and whilst navigating on the ground at complex airports. Whilst most landing approaches utilise an egocentric orientation based upon information on the ND, on all but the most modern aircraft almost all taxying operations are conducted using a chart or display oriented with north, which requires the pilot to make a rapid mental reorientation just after landing when workload is at a peak. Furthermore, airline accidents involving completely serviceable aircraft at Cali, Islamabad, Lexington and recently at Beirut serve as a reminder that despite sophisticated aids to navigation, loss of spatial awareness continues to be a contributory factor in some of the most serious airline accidents occurring in the vicinity of the airport, both in flight and on the ground. Hart and Hauser (1987) note that even during normal operations, workload and stress is highest in flight phases such as takeoff and landing. Longitudinal studies of British airline pilots by Ellis and Roscoe (1982, 1990) found that flight crews thought of their workload state in terms of the availability or otherwise of spare mental capacity. A further premise of this research was that some of the navigation tasks routinely performed by pilots are made more difficult by the way that information is presented and that the cognitive load invoked occupies working memory that would otherwise be employed operating the aircraft safely. This research examined the cognitive load experienced by pilots as they reorient to a chart and judge their relationship to important features of the spatial environment.

8.1.3 RATIONALE FOR THE RESEARCH

This research is part of a wider examination of an original construct, substandard flight crew performance (SFP). A detailed review of the aviation accident literature revealed an empirical link between confusion relating to the aircraft's heading and major errors including complete loss of control, controlled flight into terrain and gross navigation errors such as the use of an incorrect runway. A range of factors can induce cognitive overload but the area of interest in this research concerned the cognitive load invoked when pilots need to reorient themselves at short notice during either normal or non-normal operations. This study outlined situations in which a pilot might need to alternate between the egocentric orientation of the ND and the 'north up' orientation of a chart and examined the magnitude of cognitive load that such reorientation might invoke.

8.1.4 NAVIGATING A MODERN AIRLINER

Much research has been conducted into how humans navigate but much less so about how pilots navigate. Observer centred NDs represent an essential component of modern aircraft navigation with only very few older airliners relying upon analogue instrumentation for navigation. Evidence suggests that observer centred NDs improve situational awareness when compared with the displays of previous generation airliners. A growing body of research suggests that larger screens improve situational awareness (Parish et al., 1994, Prinzel et al., 2005), but it would be unwise to allow this perspective to downplay the importance of maintaining an appreciation of the real world spatial environment in the form of a cognitive map (Tolman, 1948) given the recent re-emergence of CFIT and LOC accidents involving aircraft with large NDs. Sohn and Carlson (2003) support this alternative perspective by suggesting that the constant availability of an observer centred viewpoint such as that on an ND might represent a constraining factor in spatial cognition given the frequent requirement to adopt an allocentric viewpoint, that is one that is centred on an external object or location (Klatzky, 1998).

8.1.5 NAVIGATION VERSUS WAYFINDING

Whilst all aviation professionals will be aware of what is being referred to when the term navigation is used, the term wayfinding is well known in the spatial ability literature but, as far as is known, has not previously been operationalised in the aviation context. According to Darken and Peterson (2001) wayfinding is the cognitive element of navigation whereas in this aviation related study it is more useful to consider wayfinding and navigation as separate constructs. This is because for most modern day pilots, navigation involves following a pre-planned route on an electronic ND which does not require a detailed mental representation of the environment or cognitive map as described by Darken and Peterson. However, the occurrence literature indicates loss of positional awareness accidents rarely occur when the flight crew are coupled to a pre-programmed route. Accidents like the ones at Cali (ACRC, 1996), Islamabad (PCAA, 2010) and Jakarta (KNKT, 2012) have all occurred in a context where for a variety of reasons the flight crew had departed from their planned route and were simply flying a compass heading. It is believed that this is the first research to differentiate between these two very distinct means of directing an aircraft through the spatial environment. For the purposes of this study, wayfinding refers to the process just described where a pilot derives the aircraft's position and directs its progress using features of the spatial environment. A circling approach represents a good example of the difference between navigation and wayfinding used in this study, where the initial phase of the approach is probably achieved by following a magenta line on the ND whereas the latter part involves a detailed interaction with visual features of the spatial environment, which in this study is wayfinding. At its most basic level, even in the most advanced aircraft, wayfinding may consist of dead reckoning (flying a heading for a given time) but in reality, some of the most complex circling approaches require a pilot to integrate ND, chart-based and actual spatial information on a dynamic basis as the approach progresses. In most of the accidents where pilots were wayfinding it was not through choice and their performance was very haphazard in comparison with their performance when they had been navigating. This observed decrement in pilot performance during wayfinding was one of the motivations for conducting this research.

As mentioned earlier in this thesis, statistical data relating to accidents can be misleading but it can be stated with certainty that two of the most recent CFIT accidents, one at Jakarta

(KNKT, 2012) and one at Islamabad (PCAA, 2010) both involved pilots who had intentionally selected an autopilot mode that indicated they intended to proceed on a route that was different from that they had programmed into their flight management computer. This means that they met the definition of wayfinding used in this study. It was not possible to locate any documented instances of CFIT involving an aircraft whose autopilot was coupled to a planned route and thus met the criterion for navigation used in this study. During navigation a pilot utilises stimulus responses to support the safe operation of the aircraft such as extending the flaps at a given sequential point whereas during wayfinding the pilot derives such information from knowledge of the spatial environment; for instance, when following a pre-programmed route, many modern aircraft provide a pictorial cue indicating to the pilot the point at which flaps should be extended during the approach; during wayfinding this type of decision is based upon cognitions such as how much height there is to lose and how far from the runway the aircraft is. The important point is that during wayfinding these judgments are the pilot's alone and therefore contribute to cognitive load. Navigation can proceed without recruiting spatial representations of the environment, relying more upon a memorised sequence of procedures. Navigation is more passive than wayfinding in that the pilot follows a prescribed route without the need to directly derive any of the information being utilised. This means that navigation is less cognitively complex than wayfinding. Cognitive neuroscience has elaborated upon the distinction between navigation and wayfinding by demonstrating that differential brain activation occurs during route following (navigation) and wayfinding. During route following, the caudate nucleus region of the brain is activated whereas during wayfinding the right posterior hippocampus is active (See Hartley et al., 2003; Packard & McGaugh, 1996; Spiers & Maguire, 2006). The caudate nucleus is involved in motor control (Wilson, 1912) in addition to learning and applying voluntary movements (Packard & Knowlton, 2002) whilst the right posterior hippocampus is involved in storing and using complex spatial information (Maguire et al., 2000; Moser, Moser, & Anderson, 1993; O'Keefe & Nadel, 1978). This body of research supports the notion that wayfinding represents a researchable phenomenon distinct from more routine navigation.

Most flights include a certain amount of wayfinding such as when a controller directs the flight crew towards the final approach track. Although the controller provides a heading to fly during this intercept phase, the pilot integrates information from the ND, radio beacons, distance measuring equipment (DME) and other sources to ensure a safe flight path. This type of wayfinding is well practiced by flight crews but the occurrence literature suggests that when less well-defined instances of wayfinding such as flying an unauthorised circling approach (as was the case at Islamabad, PCAA, 2010) or a holding pattern flown by sequential heading selections (as was the case at Jakarta) or during the unexpected loss of navigation capability (as was the case at Cali) flight crews can quickly become hopelessly lost. The accidents just cited span a twenty year period during which remarkable technological advances have occurred but the 2012 accident at Jakarta is not very dissimilar from the 1995 accident at Cali inasmuch as the electronic map was not providing the information needed by the flight crew so they needed to revert to wayfinding. Notably each of the three aforementioned accidents involved aircraft with observer centred (egocentric) navigation displays (NDs) as is the norm. Furthermore, in each case the pilots were misaligned with either the intended direction of landing or the direction in which they needed to fly. In the Jakarta accident CVR transcript (KNKT, 2012, p. 32) the pilots were heard trying to derive what their heading should be. At Islamabad (PCAA, 2010) the pilots knew that they were not where they should have been but lacked the cognitive capacity to remedy a very minor incorrect autopilot mode selection. At Cali the pilots incorrectly programmed their flight management computer with the result that they needed to use paper charts and wayfinding to reach the airport. In the Cali instance this required a mental transformation from the egocentric orientation of the ND to the allocentric "north up" orientation of the chart. It is not being suggested here that pilots cannot make this type of transformation but this study contends that such transformations use valuable cognitive resources that may have contributed to the SFP evident in each of these instances. Opinion is divided regarding the role of reference frame transformation in the construction of a cognitive map of the environment. A body of research by Wickens and colleagues (Haskell & Wickens, 1993; Olmos, Wickens, & Chudy, 2000; Wickens & Prevett, 1995) represents the dominant view that egocentrically oriented displays represent the optimum configuration for safe and efficient navigation. This view however, does not address the issue of adapting to a different reference frame when wayfinding is required. It should be noted that in each of the instances outlined so far, the pilots needed to adapt to a changed reference frame both quickly and at short notice, a practice which has been acknowledged by Olmos et al. (2000) can lead to disorientation. It has been suggested that the provision of large displays that can represent a broad visual field may be beneficial (Tan, Gergle, Scupelli, & Pausch, 2003, 2004) but the flight crew of an Air India Boeing 787 equipped with the largest screens currently available commenced an approach to Essendon Airport instead of their intended destination of Melbourne in January 2014 (Read, 2014); this flight crew must have been wayfinding when they made their error. Given that the majority of aviation operations involve navigation rather than wayfinding it is to be expected that the topic of how pilots will conduct the comparatively rudimentary but more cognitively demanding type of procedures that have resulted in accidents is low on the list of priorities of those involved with ensuring aviation is safe. There have been very few technical innovations in recent years that would have prevented the pilot at Islamabad (PCAA, 2010) from suffering cognitive overload or the pilot at Jakarta (KNKT, 2012) from forgetting to turn because he was thinking about how to get to his destination; anyway, both these aircraft were equipped with all of the latest technology. The most effective way of mitigating these threats would seem to be to understand them rather than ignore their existence. For instance, the use of observer centred displays in wider contexts, such as GPS displays in cars, indicates that they probably inhibit the construction of a mental cognitive map of the spatial environment (Wessel et al., 2010). So whilst an egocentric display may be optimal for navigation it may contribute to disorientation if wayfinding becomes necessary. The wayfinding literature provides a considerable amount of information relevant to the types of tasks pilots undertake when they depart from their planned route. Pilots frequently need to imagine the future location of their aircraft, a point emphasised by Endsley (1995) who defined the highest level of situational awareness as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future". Pilots not only need to imagine themselves in future locations but also in different orientations, and research indicates these processes are quite dissimilar. Imagining the aircraft on its current heading but two minutes later is the type of task required during a circling approach and is known as a *translation.* In the image at Figure 8.2 the aircraft is flying downwind and will in around two minutes turn right through 180˚ to align with the runway furthest from the aircraft (highlighted by an arrow)in the image. Until the turn commences, features such as the relative location of the taxiways and airport environment remain constant. However, in line with Endsley's model of situation awareness the pilot should be thinking about how this scene will look when aligned with the runway. This is particularly relevant at airports where there are parallel runways or taxiways as in the image. Pilots also need to prepare for a missed approach, and the literature indicates that cognitive load associated with unexpected changes during this phase can result in serious consequences. This may not seem a difficult task but it occurs at a time when flight crews are busy and rarely in the excellent visibility simulated in Figure 8.2

Figure 8.2: A simulation of an aircraft proceeding downwind

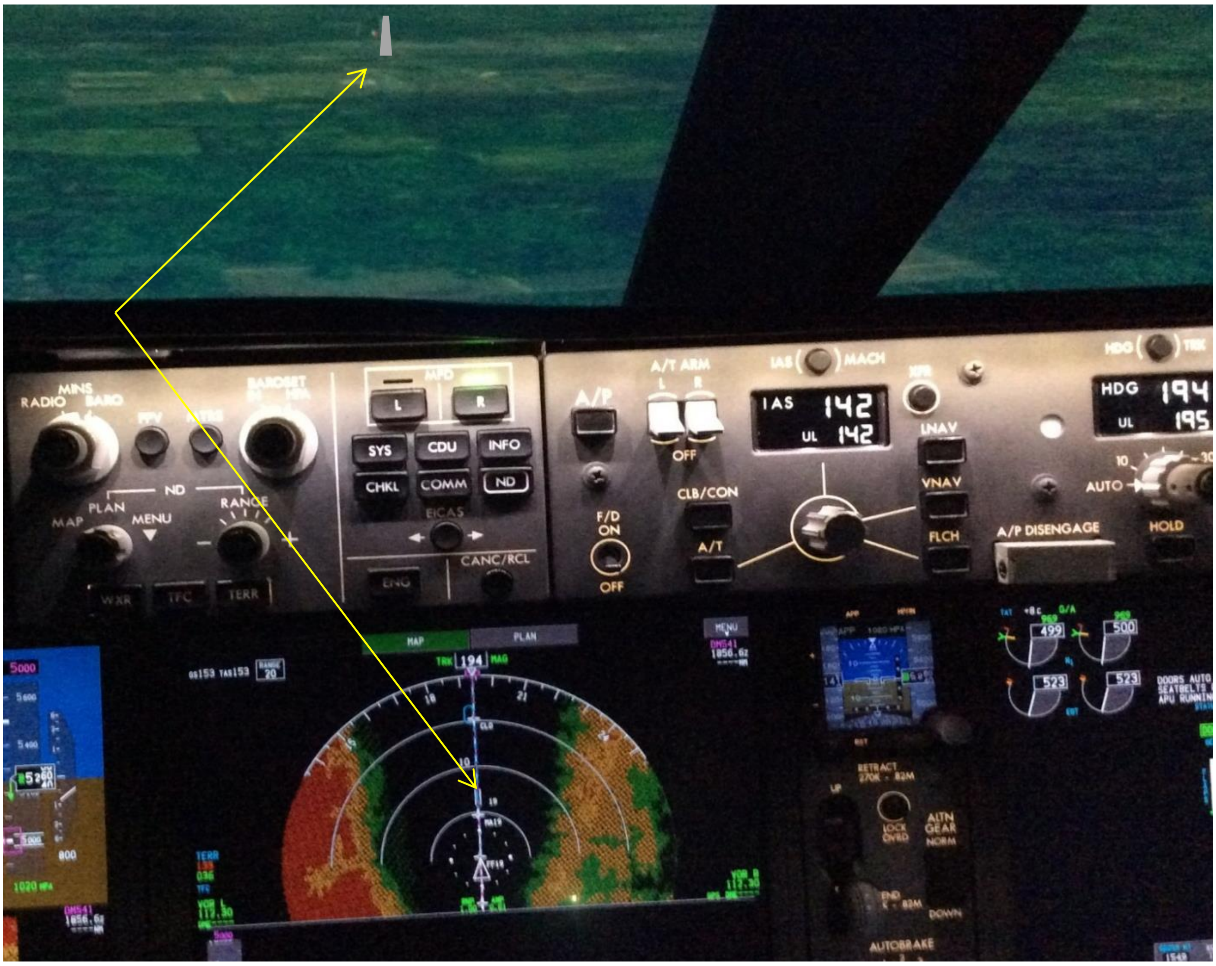
It can be seen in Figure 8.3 that once the 180˚ turn has been completed, features that were on the right are now on the left. In this case, the intended runway is on the extreme right but this would be a more cognitively challenging task if the intended runway was embedded in several potential landing surfaces. Although consideration of this type of human limitation may seem superfluous given the available technology on the modern flight deck it should be emphasised that vacating a runway in the wrong direction after landing or landing on a taxiway instead of the intended runway represents a very serious incident. See Appendix D for an example of a pilot confusing left and right in the context described.

Figure 8.3: The pilot's view when aligned with the runway

The notion that imagining an object from a different perspective from one's own invokes cognitive effort is supported by influential research by Rieser (1989) who found that participants made accurate spatial judgments when they retained their egocentric orientation despite imagining a remote location. When participants were required to imagine the relative position of an object from a different orientation, both errors and RTs increased in line with the angular difference between actual heading and the imagined direction. These changes are thought to be the result of mental rotation. The probable reason that translations appear to be less cognitively demanding than mental rotations is that in translation the objects retain their relative positions whereas in mental rotation they change. Although Rieser's research has been challenged in terms of the magnitude of the effects of both translation and mental rotation there is widespread acceptance of the general principle that imagining a different orientation from one's own heading requires cognitive effort. Darken & Peterson, (2001) emphasise that map usage as a precursor to navigation is different from map usage concurrent with navigation; if the map is used as a precursor to navigation, it is used only for planning and familiarization and no perspective transformation is required. By contrast, map use concurrent with navigation involves the placement of oneself on the map as a preliminary step. Interviews with pilots supported Darken and Peterson's ideas, with pilots reporting that when using a chart their preliminary task involved asking *where am I in relation to important features of the spatial environment and what direction am I facing?* Although the technology exists to depict the aircraft and its orientation on an electronic chart this is only currently envisaged for ground based or enroute operations not for airborne navigation in the airport environment. As far as is known, there are currently no applications that present an approach chart with all the necessary navigation text in an egocentric orientation. The accident literature indicates that it is during the approach phase that loss of positional awareness poses the greatest threat. Whereas the egocentric oriented ND always shows the spatial environment as it would appear from the cockpit, tracking the aircraft's position in relation to features of the spatial environment on a north up chart is likely to involve some degree of mental rotation. To illustrate the point being made, consider two juxtaposed examples in which the initial route is either aligned or misaligned with the egocentric reference frame required by navigation using an egocentric ND. Consider approaching an airport on a northerly track; in this case, the features appearing on the ND are arranged in a manner congruent with the northerly oriented chart's coordinates; landmarks to your east appear on your right and those to the left are to the west on both the chart and the ND. During routine navigation using an ND much of the compass rose is not visible because the ND is designed such that attention is focused on the arc either side of the egocentric path. Prior research results suggest that by adopting a navigation strategy in which canonical coordinates such as *north* or *east* are largely redundant it is likely that a viewer will establish their path through the spatial environment as the principal reference vector defining the environment's intrinsic layout (Shelton & McNamara, 2004) in other words, allocentric and egocentric reference frames will gradually coincide resulting in a reduced appreciation of, for instance where north is located. This can become a problem if a flight crew is called upon to locate a feature or geographical location referred to by a canonical reference, as illustrated by this actual fragment of a clearance which was misunderstood by a Boeing 757 flight crew in the USA:

"*Hold at teddy, northwest 10 mile legs*"

Although this incident (NASA, 2003) and other similar incidents (NASA, 2004) that resulted from the type of late communication above did not result in an accident, a very similar misunderstanding resulted in a CFIT accident at Mount Teide, Tenerife (UK AIB, 1981). The previously discussed example of a northerly bound aircraft represented an instance of low angular disparity between egocentric and allocentric reference frames. The second scenario involves situations where the egocentric and allocentric reference frames are misaligned. Consider now approaching the same airport from the north, heading south; in this case, spatial features to your left are now to the east (and vice versa). Because the nature of ND navigation is to align the allocentric and egocentric references, in this case the geocentric and allocentric frames of reference would be misaligned by 180 degrees. This poses no serious problem for ND navigation because, as has already been noted, geocentric references are largely redundant during egocentric navigation. However, potential problems do arise if it is necessary to revert to geocentric navigation at short notice because whilst in the first example the ND and the chart present a congruent representation with the aircraft proceeding northbound up the chart with features such as terrain, runways and landmarks in their correct position, the southbound pilot who needs to revert to a chart oriented with north will be navigating from the top of the chart to the bottom with all the relevant features outlined above, in reverse orientation. The process of visualising these changed spatial relationships is likely to involve mental rotation with an attendant increase in cognitive load. It is important to note that such mental rotations only become necessary in ND navigation in instances where the flight crew needs to reference alternative means of navigation such as the EFB or a chart, which implies that an increase in cognitive load is likely to be occurring in parallel with the mental rotation. For instance the flight crew at Cali who were involved in a CFIT accident (ACRC, 1996) had been conducting southbound ND based navigation prior to a runway change. Evidence from the accident report clearly indicated that they referred to paper charts whilst adapting to the new route (Flight Safety Foundation, 1998, p. 23). Having previously been accustomed to an egocentric cognitive map they now needed to forget about the orientation they were accustomed to and start thinking of their progress from the top of the chart heading towards the bottom (See Figure 8.4 below).



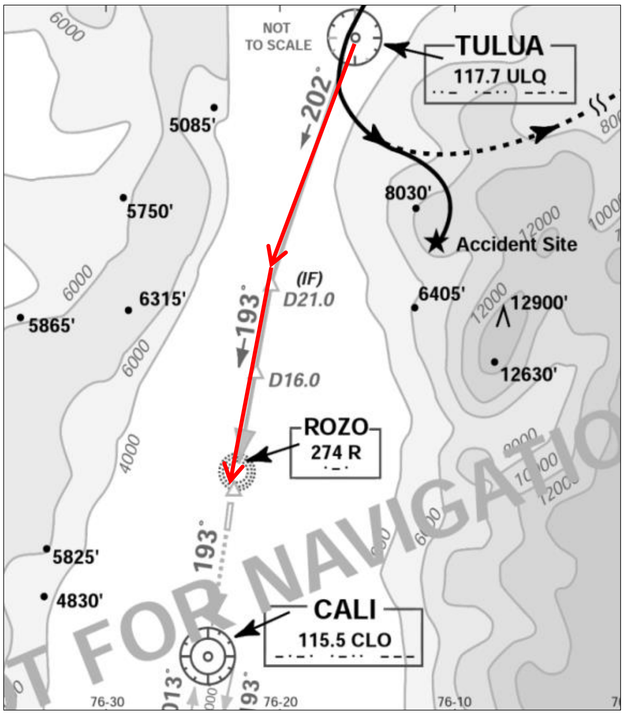


Chart Courtesy of Flight Safety Foundation (1998)

Figure 8.4

Egocentric versus allocentric representations of the approach at Cali

The image above is a simulation of an aircraft on approach to the runway involved in the Cali accident. The ND shows an egocentric orientation with the runway ahead of the aircraft (yellow arrows). The allocentrically-oriented chart on the left is of the same approach but aligned with north. The Cali flight crew needed to reorient at short notice and became spatially-disoriented. Control of the aircraft was lost, resulting in CFIT. The intended route to the runway (red line) and the accident site are depicted.

If it can be demonstrated that such reorientation invokes cognitive load it becomes easier to understand how a crew might become disoriented to the extent they did. It could be argued that all such a crew needed to do to re-establish an egocentric orientation was to orient the chart with their direction of travel. Ethnographic observations of flight crews conducted for this study indicated that during briefing, taxying and inflight they rarely oriented paper charts to the direction of travel; furthermore, the design of most EFB applications does not permit unlimited rotation of the navigation charts in flight. The observations suggest that pilots are well practiced at making such reorientations but little is known about how much cognitive load is invoked whilst this occurs. In the Cali accident the pilots were faced at short notice with a very large angular disparity between the orientation they were accustomed to and the orientation they were forced to adopt. Intuitively, a flight crew flying north who need to re-vert to a chart oriented upon north should experience low cognitive demand compared to re-version from various other orientations. How cognitive load varies with angular disparity be-tween the two orientations is the subject of one of the experiments described in this thesis. There are several theories relating to the detailed nature of how such reorientations may be handled by the cognitive system. According to Shepard & Metzler's, (1971) model both ac-curacy and RT would be a linear function of the angular disparity via the shortest path be-tween the orientation acquired from the ND and the orientation of the chart. This model has intuitive appeal due to the relative ease of performing small orientation changes in everyday life. Loftus (1978) suggested an alternative model of direction comprehension involving two steps: first, computing the nearest cardinal point to the target direction, and then "rotating" from the cardinal to the target direction. Reorientation could be performed equally well clockwise or counter clockwise. Although Loftus found that RTs were lower at the cardinal points and higher at diagonals, overall there was a monotonic increase in RTs clockwise around the compass. Explanations are further complicated by the finding from several studies that RTs for north/south cardinals were faster than for east/west cardinals. Research by Farrell (1979) involving a wide range of research populations found that up/down judgments were made quicker than left/right judgments, whereas Maki (1979) only found this effect when the spatial codes left/right were used. This could indicate that the mental association between, for instance the association between *up* and *north* is stronger than the association between *left* and *west*. Darken & Peterson, (2001) point out that that for egocentric navigation the preferred display depicts *forward* as *up*; given that this is the display orientation that pilots are accustomed to using due to the way the ND is fitted to the instrument panel, the above research may underpin any preference pilots show for fore/aft direction judgments over left/right judgments. In addition to the ability to locate oneself on the chart, pilots need to be able to imagine their future location and orientation. There are recent documented instances of wrong runway landings, landings on taxiways and gross navigational errors after landing which suggest deficiencies in the ability to imagine the relative positions of parallel runways/taxiways prior to being aligned with them or to plan in advance which direction the runway will be vacated after landing. Although some of the processes involved are similar to those just outlined, this process involves mental rotation rather than straightforward judgment of angular disparity. It is important to acknowledge the likelihood that pilots' brains may become specialised for complex navigational tasks in a similar way to that observed in London taxi drivers relative to pedestrians and bus drivers. Taxi drivers' development, storage, and use of complex spatial representations is thought to be linked to corresponding posterior hippocampal neurogenesis (Maguire et al., 2000, 2003; Maguire, Woollett, & Spiers, 2006), in other words the generation of neurons in the brain as a consequence of regularly performing complex spatial tasks. Militating against this proposition is the finding of Loftus (1978) that general populations performed at a similar level to pilots in compass direction comprehension experiments. Even if pilots are more skilled at spatial tasks than the general population, research by Thorndyke & Stasz, (1980) suggests that there are likely to be considerable individual variations. Also particularly relevant to pilots is the possibility that they might become accustomed to a certain orientation of runway simply because they usually operate from, for instance, westerly oriented runways in Western Europe or easterly oriented runways in the Caribbean. Loftus (1978) mentioned this as a possible influence but substantiating research is sparse. Jolicoeur (1985) found that as images of natural objects were rotated from a familiar orientation participants' recognition RTs increased in a way comparable to those obtained in classic mental rotation tasks. Tarr and Pinker (1989) suggest that with increasing familiarity the reliance upon mental rotation might decrease. Takano (1989) introduced the possibility that certain familiar configurations might be stored in memory and a direct match made. This speculative idea would mean that a pilot orienting to a familiar runway orientation would invoke less cognitive demand than when orienting to one less frequently experienced. During post experiment interviews with flight crews several commented that they thought they oriented to charts relating to familiar runway orientations more easily than ones they rarely experienced.

8.1.6. WORKING MEMORY, ATTENTION AND TASK DEMAND

Baddeley's (1986) influential model of the nature of working memory (WM) proposes the operation of a central executive or distributor that helps maintain and manipulate information in the mind, involved in most cognitive tasks. Although the precise detail of how attention might be allocated during the types of task examined in this study are outside the scope of this thesis it is useful to consider some theoretical concepts detailed by Pashler and Johnston (2003) that have been widely applied in trying to understand attentional limitations. The first concept is that of a strict processing bottleneck regulating workload by restricting the flow of tasks. This refers to the idea that certain critical mental operations can only be carried out sequentially. The verbal strand of this thesis provided examples of pilots who were able to perform concurrent tasks such as talking and operating the controls without difficulty much of the time so at first look it seems unlikely that the sequential processing model is appropriate for the current context. An alternative view is that there may be one or more pools of processing resources that can be divided up among different tasks or stimuli in a graded fashion. According to this account, a pilot flying the aircraft can accept a concurrent cognitive load but the remaining processing resources are spread between tasks; processing for different tasks proceeds in parallel but the rate or efficiency of the processing depends on the capacity available to the task. Exactly how this limited capacity is shared is unclear but the likely outcome of capacity sharing is a reduction in speed and efficiency in one or both tasks due to the reduction in available resources. Research spanning over a century beginning with Paulhan (1887) indicates that tasks using a similar modality tend to have an additive interference effect; more recent research by Navon & Miller (1987) reached a similar conclusion. The simplest models for predicting concurrent task and workload assess the extent to which a certain task of a known duration can be accommodated by the time available. Such models have been criticised by NASA (2010) on the basis of oversimplification for failing to consider the detailed nature and context of the dual tasks being performed. For example, it has already been stated that pilots have little difficulty monitoring and controlling their flight path while continuously conversing; in this case the conversation and the flying both fill the available time so theoretically this amount of activity would not be possible unless these two activities can be accommodated separately. Ethnographic observations indicate that workload is not as high during such activity as would be predicted by such a time occupancy model and this appears to be the result of task sharing. Although simple time occupancy models are suited to routine operations where the use of standard operating procedures provide a reliable timeline which enables pilots to predict if and when task sharing is appropriate, they represent a poor model for task management under high cognitive load. According to expert opinion (NASA, 2010) the Multiple Resource Model (Horrey &Wickens, 2003; Sarno & Wickens, 1995; Wickens, 1991, 2002, 2005) generates workload predictions that are better tailored to the potential overload experienced in dual task situations. The model's resource sharing (or resource overlap) component considers the extent to which concurrent tasks demand resources along several dimensions, a detailed knowledge of which is outside the scope of this thesis. In relation to this research Wickens' model would see the process of locating a runway visually and then accurately tracking the aircraft parallel to it as two similar visual tasks whose effect upon workload is additive. The concurrent auditory task of listening and correctly responding to a checklist would have no adverse effect upon the visual task just mentioned except for the fact that there is a requirement to base the verbal checklist response upon the cognition of visual information. This could explain why pilots under high workload sometimes respond to challenge and response checklists without actually checking an item has been completed[xiii]. If the pilot checks the item this now becomes a cognitive or perceptive task or both, which overlaps with the visual task demands adding to the total task demand of the visual modality. Task demand can be conceptually associated with one of two "regions" of task demand level (Wickens & Hollands, 2000). The first is one in which task demand is less than the capacity of resources available and therefore residual capacity exists. In this state the pilot has some spare mental capacity in the event of unforeseen circumstances. When task demand exceeds available capacity the performance of any of the tasks in progress may break down. This study is concerned with cognitive load that pushes pilots towards what Grier (2008) has referred to as the *red line* of workload.

8.1.7 COGNITIVE LOAD IN FLIGHT CREW

Cognitive load theory proposes that during the process of learning, three categories of cognitive load are experienced, *intrinsic, germane* and *extraneous*. Intrinsic cognitive load refers to information that by its nature is complex and difficult to understand; this type of cognitive load is often well defined and can be predicted and managed. *Germane load* refers to demands placed on the capacity of working memory during mental activities that contribute directly to learning, whereas *extraneous load* is caused by mental activities that do not contribute directly to learning. In the context of this research, learning about one's environment from a map aligned with the direction of travel represents a germane load whereas the research cited in the previous paragraph indicates that navigating from a map that is not oriented with the direction of travel requires cognitive effort in addition to that required for learning about the environment. Where two sources of information need to be integrated the *extraneous load* invoked during the process of establishing some degree of coherence between the two information sources may use up much of the pilot's available cognitive capacity. Renkl and Atkinson (2003) point out that when text and graphics are difficult to integrate with one another, such as in the case of a map display aligned with south and a chart aligned with north, little or no working memory capacity may remain for germane load, particularly if there is also substantial intrinsic load due to the complexity of the overall task; in such situations, learning about the spatial environment is likely to be minimal. Lansman and Hunt (1982) found that RT (the dependent variable in the experiments described here) to a secondary task was an indicator of the amount of spare capacity available whilst engaged on an easy primary task, which in turn could be used to predict performance on a subsequent more difficult task.

8.2 THE SPATIAL AWARENESS STUDY AND EXPERIMENTS

This study examined two important but distinct aspects of spatial awareness; firstly the cognitive load associated with reorienting from the egocentric orientation to geocentric orientation was examined. The second part of the study examined the extent to which cognitive load was invoked by the mental rotation required when imagining the aircraft's future trajectory.

8.2.1 EXPERIMENT ONE: ORIENTATION JUDGMENTS VERSUS COGNITIVE LOAD

The motivation for this experiment was the observation from the accident literature that confusion relating to heading information had preceded several accidents involving serviceable aircraft equipped with moving map displays[xiv]. Examples are usually characterised by inappropriate actions from the flight crew that would not have been predicted on the basis of their previous performance. An Airbus flight crew stalled their aircraft into the sea whilst visually manoeuvring to land at night near the Comoros Islands in 2009. In a similar loss of situational awareness accident the previously cited Boeing 757 flight crew at Cali also made uncharacteristic errors in a situation involving a requirement to transition from navigation based upon an electronic map oriented upon their direction of travel to a paper map oriented upon north. There are several other instances in the occurrence literature where confusion related to heading information has immediately preceded a loss of control. This research contends that if mental reorientation is required at a period of pre-existing high workload, the added cognitive load required may occupy working memory to the extent that overall performance deficits occur. The Comoros accident investigation report noted that the flight crew's "attention was focused on the management of the aircraft trajectory and tracking, and probably did not have the sufficient mental resources available in this stressful situation, to react adequately to different alarms". Similarly, the Cali investigation found that the flight crew had become subject to task overload and failed to react appropriately when it was evident they were disoriented. Neither of these reports elaborated upon the source of the cognitive overload experienced by the flight crews. The aim of the spatial awareness strand research was to learn more about how flight crews' cognitive load is affected when they face a spatial awareness task so that they can be better prepared to manage their workload, thereby reducing the likelihood that they will perform at a substandard level.

The premise of this research was that the requirement to mentally reorient occupies working memory resources that would otherwise be available for decision making and other mental tasks required by the flight crew. The literature indicates that when a requirement arises for a crew to locate the aircraft's position and orientation on a chart it is usually when the flight crew is already experiencing high workload such as when manoeuvring for an approach to landing or after takeoff or missed approach. If it can be shown that mental reorientation results in elevated cognitive load, this is an important factor that all the stakeholders in flight safety identified earlier (not just pilots) need to understand. Informal interviews with pilots indicated that orienting from the ND to a chart was a routine task that took a few seconds to achieve but usually occurred during high workload phases. When asked how they would transition to a chart, many spoke of mentally projecting the aircraft and its orientation onto the chart so as to achieve a starting point for their navigation. The research objective of experiment one was to explore the cognitive load that pilots experience while orienting to the chart. Simply superimposing an array of bearings on a chart would have been lacking in ecological validity because this bears no resemblance to any task required of pilots. Pilots frequently need to make angular judgments relating to runways such as when they derive an intercept heading for a final approach, so a runway orientation judgment task was considered to be a reasonable alternative task. The real life task under scrutiny is the process by which a pilot locates the aircraft position and orientation on a map as a precursor to navigation. An exact analogue experiment would involve multiple stimuli in a variety of positions and orientations, which would result in a very complicated set of stimuli and the possibility of introducing confounding variables. Both locating the aircraft on the chart and judging one's orientation require a judgement to be made regarding orientation. To locate the aircraft on the chart, one needs to determine a bearing from some feature on the chart and to make a judgment regarding orientation one needs to judge the angular disparity between the reference frame of the chart and the aircraft's heading. As both these tasks require angular judgments which cannot be made without knowledge of the reference frame of the chart it was decided that an experiment measuring cognitive load versus angular disparity would be undertaken. Experiment One was designed in such a way that participants were presented with successive images of runways in various orientations; this required them to locate the approach path on the chart and then judge the orientation. Clearly in the real world this process could occur when the aircraft is at any location or orientation in which case the pilot has two options, either orient the chart or orient their mental cognitive map. In the interests of experimental control the charts were presented in portrait orientation and "north up" (as is usually the case in real life) which meant that the only option for the participants was to reorient their cognitive map by making their judgments in relation to the geocentric reference frame of the chart, due north. The stimuli consisted of thirty six realistic approach charts each with a depiction of a runway. The depictions were oriented at ten degree intervals representing the three hundred and sixty degree compass rose. Although this was a compromise, Loftus (1978) examined similar phenomena using this type of stimuli to good effect.

8.2.2 EXPERIMENT ONE RESULTS

For each of thirty six runway directions RT was measured using SuperLab 5 ™ software. The results were transferred to SPSS 22 ™ for analysis. For the purpose of this research a response was considered correct if within ten degrees either side of the correct orientation. Although most responses were within this tolerance, those that were not, were usually within twenty degrees. Such responses were treated as if they had been correctly answered as the tolerance chosen for the experiment was arbitrary. Gross errors were few but each one was considered individually. It is customary to either trim or winsorize such outliers. In order to reduce the loss of data involved in trimming, any outlying response that differed from the mean by an excess of two standard deviations was allotted the closest valid value in the dataset. In cases where outliers may be an issue, Whelan (2008) recommends the reporting of median as the central tendency parameter because it is less susceptible to departures from normality. Whelan's paper makes no mention of winsorizing the data but after examination of the raw data it was considered that winsorizing would be the most appropriate means of addressing any outliers in the dataset. The graph in Figure 8.5 shows the winsorized mean RTs for each runway.

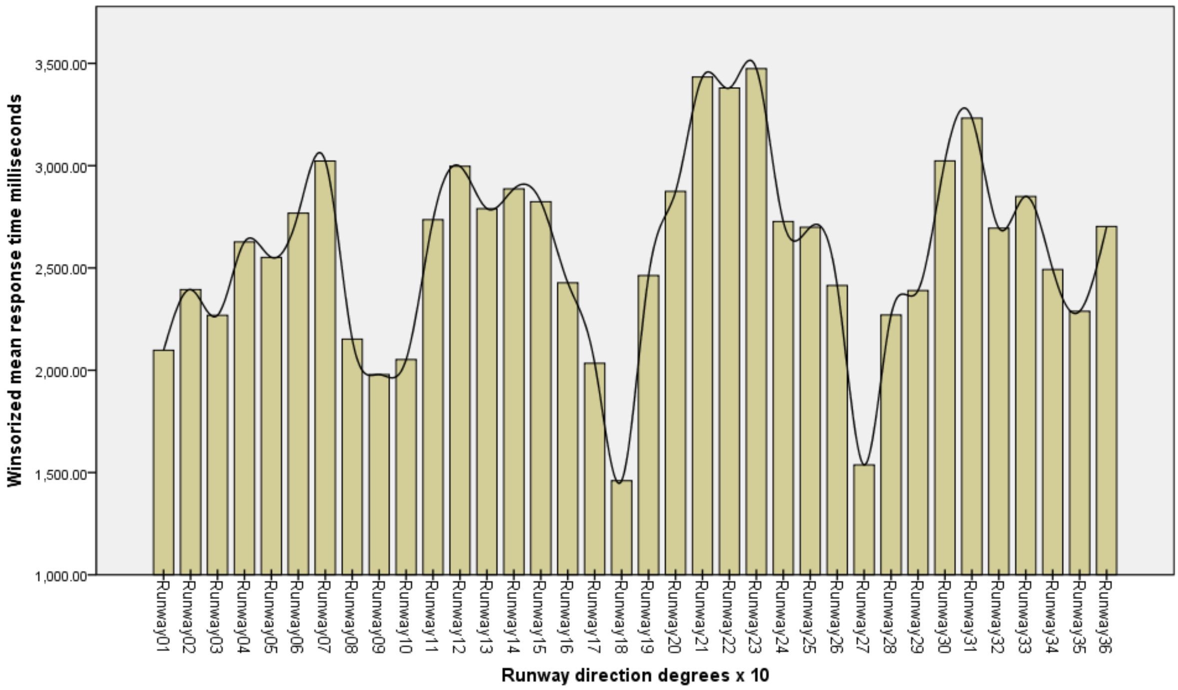


Figure 8.5: Response time in milliseconds versus runway direction

It can be clearly observed from Figure 8.5 that the east, south and west cardinal points are identified significantly faster than their adjacent orientations. Counter to expectations the northerly cardinal point exhibited a moderate increase in RT over its adjacent orientations. Significant correlations at the 0.05 or better significance level between angular disparity from the cardinals and their intercardinal points (the 45˚ point between cardinals) were obtained in all cases except the two intercardinal points immediately adjacent to the north cardinal point. This finding suggests that with the exception of northerly judgments the participants oriented upon the closest cardinal point before refining their judgment. The RTs exhibited around the northerly cardinal point suggest that judgments in this region are handled differently by the cognitive system. Post-test interviews indicated that eighteen participants were aware of orienting to the cardinal points as a preliminary step in identifying the runway orientations in the experiment. Two participants said they mentally rotated around the compass in a clockwise direction. The results above militate against this hypothesis and as all results were de identified it was not possible to confirm whether these participants' introspections were founded. Five participants said they identified familiar orientations; if this were the case, it would be expected that the participant group, who were all based at airports with either westerly or south westerly oriented runways, might identify such runways quicker. There was no evidence of this; in fact the south westerly oriented experimental depiction yielded among the slowest RTs. Nevertheless the familiarity hypothesis was mentioned by a quarter of the participants in the interviews so it should not be dismissed. Four participants commented that they needed to think about whether a northerly runway should be typed on the keyboard as 36 or 00, a factor that might account for the small spike in RT at north. This effect should not be minimised because a runway aligned exactly with due north is unique inasmuch as that although it is referred to as runway 36 neither the aircraft instrumentation nor the approach chart will depict the runway orientation as 360˚ but as 000˚. Contrary to expectations, RTs for northerly oriented runways were slightly slower than for southerly oriented runways. Due to the design of the experimental stimuli, in order to identify a northerly facing runway a viewer would need to look at the bottom of the chart where the final approach track is displayed by an arrow flight; a linear search commencing at the top of the chart might account for the almost one second increase to identify a northerly oriented runway over a southerly oriented one.

8.2.3 EXPERIMENT ONE DISCUSSION

Experiment one replicated and elaborated upon research by Loftus (1978) which examined the processes by which information corresponding to a particular direction is comprehended and utilised. Whereas Loftus's participants were university students and military pilots, this research involved current airline pilots who were well acquainted with the type of navigation being performed. Furthermore, to ensure ecological validity the stimuli consisted of charts that closely resembled the ones used during actual operations. The results indicate that, in line with Loftus (1978), pilots utilise the cardinal points of the compass when making spatial judgments. This experiment examined the process of locating one's position on a chart as a precursor to wayfinding. The process of identifying a runway direction on a chart was chosen because it required the observer to locate the runway centreline extension and to make a judgment regarding its orientation. This was considered a reasonable analogue of the preliminary process involved in chart based wayfinding reported by many of the participants. The experiment indicated that all the cardinal compass points except due north were associated with low levels of cognitive load, whilst judgments relating to their inter cardinal points were most cognitively challenging. This means that the first part of the task (locating the aircraft's position on the chart) is made easier if it is situated close to either the 90º, 180º or 270º bearing from whichever point on the chart the observer chooses. As a precursor to wayfinding, the pilot needs to determine by whatever means available, a bearing from some feature whether from the ND or more basic cues. In the Cali CVR transcript the captain was clearly heard trying to select radio beacons to locate the aircraft's position when the aircraft's FMC and electronic map display became unusable so the likely process of establishing position under such circumstances can be substantiated on the basis of evidence (Flight Safety Foundation, 1998, p. 23). The second part of the experimental task involved mental rotation (which is examined in experiment two) because once a bearing had been established by participants there was a requirement to judge its orientation. In experiment one this was probably made easier because the orientation was always the reciprocal of the bearing, which pilots are easily able to derive; in real life the aircraft could be oriented in any direction but this would have resulted in a very complex experiment. Despite this experimental limitation several participants *(n=9)* described mentally orienting to the direction of the runway depiction in order to derive the runway direction and commented that this process was more difficult if there was a large angular disparity between their viewpoint and the imagined viewpoint. The reason this is important is that in almost all cases where the pilot takes responsibility for leaving the planned route in the vicinity of the airport, whether to save time or because it is the only practicable means of landing on a particular runway, reference will need to be made to a chart (or its electronic equivalent). There are very few instances where wayfinding in limited visibility can be safely achieved by using the ND and visual reference alone. Even if a chart is not used, the pilot will need to form a mental appreciation of the spatial environment in order to remain clear of obstacles. The results of experiment one indicate that the overall angular disparity between the pilot's egocentric orientation and the orientation of a chart aligned with north is less of a factor in the elevation of flight crew cognitive load than is suggested by Shepard and Metzler (1971) but is more closely related to angular disparity from three of the four cardinal points of the compass. This suggests that what is being observed is not a process of mental rotation but one of identification of a more or less familiar orientation. Such familiarity for cardinal points may have its foundations in the referents of orthogonality provided by the human body; for instance, when the arms are extended in the plane of the shoulders they describe a right angle to an observer's egocentric orientation, which might facilitate the recognition of cardinal points based on their biological reference frame over orientations with less obvious relationship to their body's natural reference frame. Likewise, the earth's gravitational field provides an omnipresent vertical reference with a largely invariant relationship to the horizon. Overall, there is no clear explanation for the counter-intuitive finding that the northerly orientation did not yield the fastest RTs, particularly as this was not evident in other similar research. It could be relevant that north/ south aligned runways are much scarcer than east/west aligned runways in the UK where all these pilots were based; also when north/south aligned runways are used, the prevailing wind in the UK usually results in a southerly oriented landing, so a northerly oriented runway may represent a less familiar spatial configuration to the pilots who participated. The longer RT for the northerly cardinal suggests that pilots probably commence their search at the top of the chart (where the 180˚ oriented extended centreline was situated) and search down the chart until they locate the stimulus they are looking for. During ND navigation the focus of attention is usually at the top of the ND where most of the important information is located so this might underpin the results with reference to north/south judgments.

Wayfinding is a dynamic process; once the location and orientation is known there is an on-going requirement to mentally plot the aircraft's present and future progress, a process that is likely to involve mental rotation. Some of the most complex circling approaches cannot be flown without reference to terrain and obstacle information that is only available on a chart, not the ND. Furthermore some circling approaches are so complex that intrinsic cognitive load is high already; also in some cases extraneous cognitive load may inadvertently be introduced, as was the case at Cali and Comoros where communication problems were also evident. Germane cognitive load in the form of essential activities such as configuring the aircraft for landing also contributes to the overall workload. Due to the task sharing required during wayfinding it would probably not be possible to continuously follow the aircraft's progress on the chart so it is likely that the process of fixing position and orientation on the chart would need to be repeated several times. Given that each repetition would occur in a different location on the chart with a different angular disparity from the chart orientation, and that the pilot would be likely to retain some spatial knowledge from previous judgments it is very difficult to attempt to quantify the effects. What can be said with some certainty is that in cases where a pilot either chooses, or is forced by circumstances to revert to wayfinding rather than conventional navigation there will be a requirement to integrate spatial knowledge from the real world and ND with a representation of position and orientation on a chart or its electronic equivalent, which is likely to be oriented with north at the top. The process of locating the aircraft position on the chart is subject to considerable variability; if, as is often the case in circling approaches, the aircraft position is known with a high degree of precision immediately in advance of wayfinding it may only be necessary for the pilot to mentally rotate in order to follow the aircraft's progress. If, as was the case at Cali and Islamabad (PCAA, 2010) the pilot has to unexpectedly revert from navigation to wayfinding, and does not know accurately where the aircraft is located, the priority will be to identify where the aircraft is before attending to where it is going. As highlighted by Wessel et al. (2010) the egocentric orientation of the ND is not optimal in terms of forming and maintaining a cognitive map of the spatial environment based upon a geocentric reference frame such as a northerly oriented chart so it is unlikely that a pilot unexpectedly faced with transitioning from an ND to a chart will immediately be aware of the aircraft's precise location on a chart. In both the Cali and Islamabad occurrences a rapid decrease in pilot performance was symptomatic of a sudden increase in cognitive load. It is also noteworthy that the phenomenon of a sudden decrease in piloting performance during unexpected tasks that require reorientation is apparently resistant to technological advances such as EGPWS, having been evident at Mount Teide, Tenerife in 1979, Cali in 1995, Comoros in 2009 and Jakarta in 2012.

Although the statistical patterns identified in experiment one strengthen the case for reorientation as a factor in cognitive load elevation and consequential pilot performance deficits, the important lesson from this part of the study is that pilots need to consider carefully the threats posed by wayfinding and at least understand the human limitations involved. Of the 40 pilots who participated in the two experiments none had heard the term "mental rotation" although most recognised the phenomenon after the experiments. As expected, none had considered the distinction between navigation and wayfinding.

8.2.4 EXPERIMENT TWO: REMOTE PERSPECTIVE JUDGMENTS VERSUS COGNITIVE LOAD

The motivation for this experiment was to explore why flight crews sometimes exhibit SFP in situations where navigation tasks require a mental rotation. Instances of flight crews turning the wrong way, proceeding in the wrong direction during taxying, lining up on a misaligned runway, and others provide empirical evidence that flight crews can find it cognitively challenging to imagine the relative locations of significant features of the spatial environment when viewed from a remote perspective. As previously mentioned, Endsley (1995) highlighted the necessity for pilots to imagine the aircraft's future progress including its location and orientation in order to retain situational awareness. Although documented instances of flight crews who land on a runway or taxiway parallel to their intended landing runway or turn the wrong way during a missed approach or after landing indicate that those involved did not adequately visualise their future orientation, this was only a side issue in this research. This research was concerned with the sudden decrease in piloting performance that appears to occur when an unexpected or sudden requirement to transition from ND based navigation to wayfinding is required. Whereas experiment one was concerned with the initial process of locating oneself in a spatial environment by orienting to a feature on a chart, experiment two examined the cognitive load invoked when a pilot needs to imagine the spatial environment from a remote perspective. This is the type of task that the pilots at Cali were attempting in the minutes before they crashed into terrain. More specifically they were faced with the need to transition from the egocentric orientation of the ND to information on a chart geocentrically aligned with north. This experiment examined the nature of cognitive load experienced by flight crews when they make this type of reorientation.

As with experiment one, this experiment forced participants who were accustomed to an egocentric orientation to make spatial judgments based upon a geocentric reference frame. This was achieved by presenting all the stimuli in a “north up” geocentric reference frame. The experiment was designed to measure the cognitive load that pilots experience when changing their reference frame from egocentric to geocentric. Although there was no hypothesis, previous research suggested that cognitive load would increase with increased angular disparity between the egocentric perspective of the pilot and the orientation to be imagined. As in experiment one, it was impracticable to present stimuli from a wide range of aircraft orientations so the pilot’s orientation was fixed by presenting the charts used as stimuli in a “north up” orientation. By rotating the runway depiction in 45º stages it was possible to create eight different angular disparities. The choice of 45º stages was based on the experience of experiment one, which indicated the importance of both cardinal and diagonal angles. Another lesson from experiment one was that participants thought 36 stimuli made the experiment overly long. For this reason, experiment two was limited to one block of 16 trials. Participants viewed 16 approach charts on a laptop screen. Two charts were prepared for each of eight orientations, separated by 45º. Each pair of charts included one depicting terrain left of the final approach course and one depicting it on the right. In addition to forcing the participants to make a judgment from the perspective of the depicted runway direction, the provision of two randomly presented depictions of terrain increased the amount of data from what was a quite small participant pool by requiring two responses for each orientation. The experimental task was to judge as quickly as possible whether the terrain was located to the left or right of the final approach track depicted on each chart when viewed from that perspective.

8.2.5 EXPERIMENT TWO RESULTS

The error rate was low, with only four errors in the dataset of three hundred and twenty responses. This low error rate was predictable partly because the task was one that pilots would be practiced at performing but also because they would be motivated to respond with a correct response out of professional pride. Although the focus of experiment two was the measurement of RT, if pilots' main focus was upon accuracy, the ecological validity of the experiment would likely be enhanced because the experiment would be measuring how pilots behave in the real world. To address the four incorrect responses, each one was replaced by the closest correct response in the dataset, though this had very little effect on the mean RTs. A Shapiro-Wilk test found that the data from experiment two were not normally distributed and there were also several outlying scores. Nonetheless there was a moderate overall increase in median RT with angular disparity from north both clockwise and counter clockwise. Figure 8.6 is a boxplot showing the RTs for each runway direction. Due to the non-normal distribution of the data a Kruskal-Wallis anova test was used to determine significance levels.

The Kruskal-Wallis anova test only determines if there are statistically significant differences between groups of an independent variable on a continuous or ordinal dependent variable (in this case RT) so it is not possible to claim a significant linear effect due to angular disparity from north to south although the median RTs in Figure 8.6 show a trend in that direction.

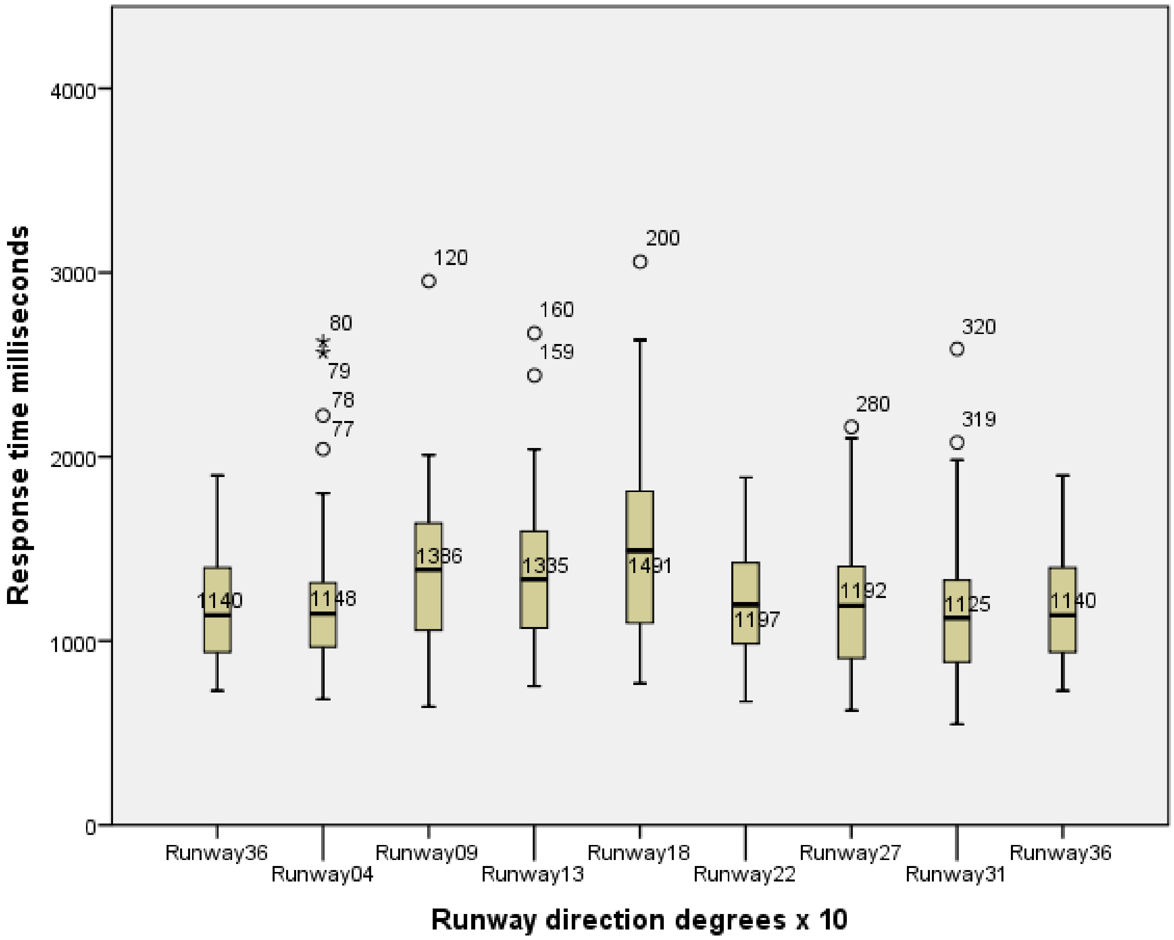


Figure 8.6 Runway direction versus response time

The Kruskal-Wallis anova showed a statistically significant difference in RTs between groups = 16.088, $p = 0.003$, with a mean rank RT of 80.76 for runway 36, 82.34 for runway 04, 109.28 for runway 09, 107.10 for runway 13 and 123.03 for runway 18. Table 8.1 shows the test statistics.

Table 8.1 Response times and test statistics for runway directions 36 to 18 clockwise

Ranks

	Runway	N	Mean Rank
Response time	36	40	80.76
	04	40	82.34
	09	40	109.28
	13	40	107.10
	18	40	123.03
	Total	200	

Test Statistics[a,b]

	Response time
Chi-Square	16.088
Df	4
Asymp. Sig.	.003

a. Kruskal Wallis Test
b. Grouping Variable: runway

The Kruskal Wallis test showed a statistically significant difference in RTs between groups = 17,669 $p = 0.001$, with a mean rank RT of 133.79 for runway 18, 99.45 for runway 22, 91.78 for runway 27, 85.74 for runway 31 and 91.75 for runway 36. Table 8.2 shows the test statistics.

Table 8.2 Response times and test statistics for runway directions 18 to 36 clockwise.

Ranks

	Runway	N	Mean Rank
Response time	18	40	133.79
	22	40	99.45
	27	40	91.78
	31	40	85.74
	36	40	91.75
	Total	200	

Test Statistics[a,b]

	Response time
Chi-Square	17.669
Df	4
Asymp. Sig.	.001

a. Kruskal Wallis Test
b. Grouping Variable: runway

Several conclusion follow from these results; firstly the general finding of experiment one that RT varies with angular disparity from a chosen reference frame is supported although the effect in experiment two was more random than in experiment one. It can however, be concluded that the shortest RTs were in the quadrant centred on the chosen reference frame (in this case north). Also the longest RTs occurred at an angular disparity of 180º from the reference frame. The remainder of orientations showed no clear pattern except that unlike experiment one there was no preference for orientations close to the cardinal points.

8.2.6 EXPERIMENT TWO DISCUSSION

Experiment two elaborated upon the findings of experiment one, extending beyond the initial task of reorienting to a misaligned chart into the domain of imagining oneself in a remote location and reporting the location of an object from that perspective. Unlike the experimental task in experiment one, experiment two did not require participants to specify the runway orientation, which appears to have resulted in participants making no reference to the cardinal points. The shortest median RTs were between runway 31 and runway 04, an area where it is unlikely that a mental rotation was necessary to make the left/right judgment needed in this experiment. Overall, the shorter RTs were in the northerly quadrants and the longer were in the southerly quadrants, supporting the mental-rotation hypothesis (Shepard & Metzler, 1971). RTs for runway 09 were almost two seconds longer than for runway 27 which could suggest a clockwise search was performed in order to mentally face east by searching for the nine o'clock position on the compass. RTs for runway 13 were over a second slower than for runway 22 which have equal angular disparity from the northerly reference frame, which could also suggest a preference for a clockwise visual search during mental rotation. These results suggest that this task is handled in a complex fashion which only involves mental rotation when a scene cannot be visualised without rotating to align with it. Angular disparity between runway orientation and reference frame influenced RT less than the distance in a clockwise direction between the reference frame and the orientation to be imagined. This finding is in line with research by Kosslyn et al. (1978) who found that response latency to transfer covert attention from one mentally represented location to another was a function of the distance between the two locations. Loftus (1978) also found a monotonic increase in RTs in a clockwise direction around the compass. In combination these results indicate that working memory capacity will be occupied to a low level when it is possible to visualise a scene without performing a mental rotation and to a higher level when a mental rotation is required. Whether or not a mental rotation is not required, the results indicate that cognitive load may be influenced by the distance it is necessary to search in a clockwise direction for the required orientation. The longer RTs for runway 13 compared to runway 22, both of which probably required a mental rotation, suggest that the two effects may be additive. These results indicate that the effect of spatial judgement tasks on WM and cognitive load is multifactorial and therefore difficult to predict. Hinson et al. (2002) are among those who have demonstrated that increased WM load produced by secondary tasks leads to decrements in decision making ability.

8.2.7 LIMITATIONS OF THE SPATIAL AWARENESS STRAND STUDIES

Casting a critical eye on the utility of the experimental results it is important to note that in all the gross navigation error accidents cited in this thesis the pilots' situation was worsened by the fact that the aircraft was turning at or around the time the flight crew became spatially disoriented. From an experimental standpoint this is a confounding factor because it could be argued that the dynamic nature of their situation made it much more difficult to make judgments because of the rate of orientation change. Although experiment two did not provide strong statistical support for mental rotation as factor in cognitive load elevation, there was a statistically significant variation in RT for different runway orientations. This finding may be even more important than the mental rotation hypothesis because if the effect upon cognitive load is more random that at first expected, it is reasonable to conclude that almost any task that requires reorientation could raise cognitive load demand in an unpredictable fashion. The actual position prior to this research is that as far as is known, no previous research has attempted to understand why pilots flying up to date aircraft continue to lose positional awareness and as a consequence lose control or crash into terrain when faced with a seemingly simple navigation task at short notice. Even if all that can be concluded from experiments one and two is that if it is necessary for a flight crew to fix their position on a chart and make a judgment at short notice regarding their direction of travel or their relationship to features of the spatial environment, required cognitive resources might exceed available cognitive resources, it represents considerably more evidence-based knowledge than could be located in the existing literature. So although the claim that pilots can become disoriented when they need to adapt to a changed reference frame is probably not news to those involved, this may be the first study to operationalise some of the factors involved. Furthermore, although pilots are likely to be aware that they feel under pressure when they need to make these judgments, it is doubtful whether support workers who have never been exposed to such a situation would possess the same insight.

From a methodological standpoint both experiments involved fewer participants than would have been desired. However, they were high quality participants who had an interest in participating. Based upon existing research into similar phenomena with many more participants (e.g. Wohlschlager & Wohlschlager, 1998), experiment one is likely to have arrived at a similar conclusion if a larger participant pool was recruited. Experiment two was completely original and although the participant pool was small, it provided statistically significant results. However, the results did not provide irrefutable support for the mental rotation hypothesis although there was evidence of increased RTs where mental rotation was likely to have occurred.

Although RT is an established method for measuring cognitive load, it emerged during the research that pilots are more concerned with accuracy than with speed. Whilst this is to be expected in safety critical activities such as flying, it does call into question the ecological-validity of RT measurement in this context. Finally, the absence of measures of validity statistics should be addressed; firstly, the research by Loftus (1978) which inspired this study also included no validity statistics, probably because Loftus considered his research to be "preliminary and exploratory". The research outlined here should be viewed in the same context because where statistics were provided, no claim as to causation was made and therefore internal predictive validity was not an issue. Although the stimuli used were realistic, it is almost certain that a simulated scenario would increase the realism; it is debatable whether the expense of such an experiment would be justified given that the relatively simple experiments outlined here provided experimental evidence relating to the very specific constructs being examined. In terms of construct validity, the constructs were straightforward and the experiments measured those constructs; determining whether these are the processes that pilots use would involve far more complex methods, some of which are outlined in the next section.

8.2.8 FUTURE RESEARCH

Although this was a small scale study, it addressed a big and important safety issue. However, the researcher's intuition is that more extensive research would only support the general finding of this study that adapting to a chart from an ND appears to require cognitive effort. It is important to acknowledge that there are many methods of measuring cognitive load such as Nygren, (1991) who researched psychometric techniques, and Beatty and Lucero Wagoner (2000) who identified three task-evoked pupillary responses in response to cognitive load. Although RT measurement was effective in the current relatively small scale study, it is possible that there are more robust methods of cognitive load measurement. However, it should be remembered that many of these methods such as those used by Ellis and Roscoe (1982, 1990) cited earlier involved attaching sensors to operating pilots which might have influenced the data obtained. If it were possible to routinely monitor pilots' workload state via neurobiological means without altering their behaviour the data obtained would probably be an effective predictor of impending performance decrements given the empirical link between the two. Earlier it was asserted, on the basis of literature review that when pilots deviate from their programmed route, they are wayfinding. This was a bold claim given that this research was unable to find any existing reference in the aviation literature to a similar construct to wayfinding as defined in this thesis. On the basis of informal interviews with pilots there is little doubt that many recognise the distinction between navigation and wayfinding and it is likely that given the technology that exists today a more scientific claim regarding the difference between the two phenomena in the aviation context could be established. It was outlined earlier how brain neurogenesis has been identified in individuals who have to make frequent spatial judgments; it would be interesting to examine the pattern of brain neurogenesis of airline pilots who developed their navigation skills before the widespread use of observer oriented electronic map displays and those who have experienced nothing else. If it could be demonstrated that pilots are losing or have lost the capacity to navigate safely without modern technology then two options exist, either train them or prohibit them from navigating without suitable technology; neither of these options is likely. Modern simulators are capable of replicating realistic scenarios, and the technology exists to identify differential brain activity that could indicate wayfinding was being undertaken. However, referring back to section 4.4 of this thesis on stakeholders, someone has to pay for such research and it is hardly likely to be the developers of the technology the general premise of this research challenges. Similarly, in the commercial world it is unlikely that the airlines would allocate resources to identify a phenomenon for which they would then have to devise mitigations. Although the phenomena described in this section have a particular relevance at present due to the current narrative regarding airline pilot skill levels highlighted in the appendix to the Buffalo report (NTSB, 2010a), it is unlikely that pilots being trained today are going to be coached in the navigation skills of yesteryear, despite the fact that the flight crew at Jakarta in 2012 and more recently an errant Airbus flight crew at Bristol, UK (UK AAIB, 2015) were engaged in just that type of process. The best that can be hoped for is that this research will alert pilots who only rarely navigate without the aid of an observer-centred ND to the possibility that they may have become de-skilled in the type of navigation being undertaken above.

Finally, given that the unstructured interviews conducted for this research indicated that at least ten of the twenty participants in each experiment had never previously considered orientation tasks like those in the experiments to be a risk factor, it is likely that those who support them are also unaware. Accidents at Mount Teide, Tenerife in 1979 and at Sochi in 2006 highlighted how quickly pilots can become confused when instructions are communicated poorly (this was examined in detail in Section 7.2). The utility of the SFP research outlined in this thesis is in its potential to ensure that support workers like the two air traffic controllers cited above, understand their role in ensuring aviation is safe. Research relevant to this aim falls under the research umbrella of emotional intelligence (EI) and is broadly concerned with metaphorically putting oneself in the other's shoes by understanding and empathising with their situation. Clearly in order to empathise, it is necessary to understand the implications of one's actions. EI is taught in several military contexts including the Royal Air Force and the USAF (See Livingstone et al., 2002 for a paper prepared for the Canadian Air Force), so the importance is beginning to be acknowledged. EI research might examine to what extent the agency that designs a complicated circling approach or a confusing taxiway layout has considered the cognitive implications of their actions, or whether they even understood that there were cognitive implications. Section 4.4 on stakeholders outlines some of the factors that might militate against a transformation that was not supported by strong evidence. Both this thesis and CAA research (2017, p, 24) identified a persistent disconnect between pilots and those who support them. The following narrative from a pilot commenting on his view of the attitude of some air traffic controllers to pilots is illustrative:

"Why can't you chaps on the other side of the radio just do as you are told?'

(CAA, 2017, p. 24).

The CAA research commented that the tension between controllers and pilots "may be worth further investigation". This research provides evidence that on occasions flight crews find it very difficult to "just do what they are told" and the research outlined in this thesis represents the type of "further investigation" suggested by the CAA.

CHAPTER 9

THE CONTEXTUAL CUEING STRAND AND EXPERIMENTS

9.1 INTRODUCTION

A recurrent feature of the SFP related accidents and incidents examined in this research was that the flight crews involved had frequently formed in incorrect perception of their current or future situation. This observation is supported by research by Jones and Endsley (1996) which reported that 76% of situational awareness (SA) errors made by pilots could be traced to misperception of necessary information. The current study set out to identify repetitive instances of SFP in which the flight crew's behaviour suggests that they misperceived their situation due to the influence of contextual cues. Existing research into the contextual-cueing paradigm has mainly examined how visual attention is affected by context but careful reading of the relevant literature indicated that similar processes might underpin some of the behaviour exhibited by flight crews who experience repetitive contexts. So whilst this research was loosely based upon the contextual-cueing paradigm, the ideas proposed and the methods used were original. Based upon evidence from official accident and incident reports, three specific sources of misleading contextual information were proposed and conceptualised. Although the experiments outlined here examined specific phenomena such as response to TCAS advisories and repetitive system configurations, this section set out to demonstrate how contextual cueing offers a plausible explanatory framework for many of the diverse instances of SFP contained in the literature.

9.1.1 WHAT IS CONTEXTUAL CUEING?

Contextual cueing describes the proposal made by Chun and Jiang (1998) that visual context guides the deployment of attention, critical for processing complex visual inputs. Global properties of a scene are thought to affect behaviour by prioritizing attention to contextually salient regions. Although Chun and Jiang were exclusively concerned with the effect of visual context, the principle that context can influence behaviour is one that can be applied more generally. This study elaborated upon the basic concept of contextual cueing to encompass a range of issues that may be relevant to the occurrence of SFP.

9.1.2 WHY IS CONTEXTUAL CUEING RELEVANT TO SFP?

This study was inspired by ethnographic observations of flight crews' reactions to contextually specific alerts which suggested that they were frequently able to predict the meaning of an alert before they had actually allocated time to look at it. For instance, on early Boeing 737 aircraft a landing gear warning horn occurs in flight when a particular combination of thrust, landing gear and flap configuration are used. Because this combination occurs on a regular basis during normal deceleration, flight crews appear to have become accustomed to hearing the warning in that contextual situation. Ethnographic observations indicate that the warning horn has become so associated with those particular contextual conditions that it is frequently cancelled with no analysis whatsoever. Although the role of positive predictive value (PPV) in decision making has received little attention in relation to aviation it has been examined by Lee and Mark (2010) in intensive care units as a predictor of risk. PPV has also been tested experimentally by Getty et al. (1995) who found that high PPV was related to increased latency in human response to alerts. In support of this finding, the aviation related literature contains several instances of flight crews ignoring alerts that could be considered to possess high PPV. The example of the Boeing 737 landing gear warning horn above suggests that

PPV varies with context because in contexts other than the precise one described, it is improbable that a landing gear warning would be cancelled without analysis. The instance just outlined was specific to a certain phase of flight (decelerating) but the occurrence literature also suggests that certain system configurations are associated with repetitive instances of error, particularly related to misattribution. For instance, there are repetitive instances in the occurrence literature of landing gear retracted landings occurring in a systems-status context which includes a non-normal landing flap configuration. These occurrences are usually characterised by the flight crew's failure to react to warnings related to the retracted status of the landing gear. It appears that the prior knowledge of the altered system status cues the flight crew to expect warnings, and as a consequence they misattribute unrelated warnings to the system status. Even when system status is normal, there is some evidence that flight crews possess precognitions relating to some alerts. A captain at Jakarta (KNKT, 2012) took just 11 seconds to conclude that his EGPWS terrain database was incorrect and that this justified ignoring it. Terrain databases are very rarely wrong so it is highly unlikely that he would have made such an assessment if he had not been operating in a geographical area in which the aircraft was not usually flown. A similar phenomenon was evident at Cali where the captain wasted time doubting the indications on his navigation instruments. Expert analysis (Flight Safety Foundation, 1998, p. 13) speculated that he may have been influenced by his knowledge that radio beacons in that area had been the subject of sabotage in the past. In a similar vein, when a flight crew is familiar with a certain type of alert or indication there is some evidence (See UK Airprox 2014 & 2015) that they default to the response they are most used to performing, which may not be optimal for the prevailing context. The underpinnings of this type of misperception have been described by Gibson and Spelke (1983) who suggest that the key to perceptual learning is the education of attention, learning which variables to attend to and which to ignore. Through practice and experience, attention becomes fine-tuned toward the relevant information. More importantly though, the more perceivers know what is wanted and where and how to look for it, the less they bother with irrelevant and unhelpful information in performing a task. So if a pilot's previous experience of for instance, setting the flaps as the aircraft leaves the gate is that they usually extend correctly it is conceivable that the pilot will not be motivated to check the indication. Although alternative explanations have been proposed for omitting to extend the flaps in this contextual situation, explanations such as resumption lag and post-completion error underplay the clear role of repetitive contexts in this type of error. The process whereby knowledge of the type just described is acquired without conscious awareness has been defined by Reber (1989) as implicit learning (IL). He notes that this type of knowledge is often tacit in nature, in other words it defies verbal or written description. In straightforward language, tacit knowledge represents what individuals unconsciously believe they know about the prevailing contextual situation. For instance a pilot who plans an approach and landing with the flaps retracted due to a system malfunction knows to expect some unusual alerts associated with that system configuration but the report relating to an accident involving exactly this context at Barcelona in 2007 (CIAIC, 2007) indicated that a range of other completely unrelated alerts such as enhanced ground proximity warnings (EGPWS) and landing gear warnings were also ignored. Given that flight crews are not trained to respond to contextual information in this way, the empirical evidence suggests that this learning occurs without their knowledge. Furthermore, whereas in most contexts IL could be seen as conferring a cognitive advantage, this example suggests that in the aviation context it represents a potential threat. An important question is why having made a mistake due to contextual influences and IL, the flight crew often fails to respond to multiple cues that should alert them to their error or omission. The literature relating to the allocation of attention in such cases is extensive but there is wide agreement that certain stimuli are filtered when concurrent tasks are undertaken. Early theoretical models proposed that the first stimulus that attracted attention would result in later stimuli being completely ignored (Broadbent, 1958) but as knowledge improved it became widely accepted that multiple stimuli could be attended to at once (Deutsch & Deutsch, 1963) but at a less deep level. Current thinking broadly reflects the views of Duncan (1980) that even stimuli that are not consciously attended to are probably processed without the individual knowing. Treisman (1964) proposed a model in which the first attended stimulus received more complete processing than subsequent stimuli. She also emphasised the role of context by highlighting the importance of the relevance of a stimulus in determining whether it is attracts the attention. This is particularly pertinent to this study because, for instance, engine noise or the sound of the extended landing gear may not be recognised as relevant to a pilot concentrating on flying a complicated approach because these stimuli are usually taken for granted. The important aspect of Treisman's model is that relevance must be identified and addressed, and this is one of the areas where the accident literature indicates that some pilots become adversely influenced by context. The current study examined the extent to which pilots assume that certain conditions are met on the basis of their previous experience of similar contextual conditions. The extract below is from the report into a landing gear retracted landing at Houston airport:

"*The landing checklist was not performed, and the flight crew did not confirm that the gear was down and locked. The gear warning horn sounded during the approach, indicating that the landing gear was not extended, but it was ignored. The GPWS sounded an alert 19 seconds before impact and was ignored. Unaware that the gear was not down, the captain assumed control of the airplane and made a wheels up landing".* (NTSB, 1997a, p. 38)

This research contends that three distinct categories of context appear to contribute to instances of SFP in the literature. Flight crews have been observed to make false assumptions related to alerts and warnings based upon previous knowledge gained in similar contextual conditions. There is also evidence that in certain phases of flight some flight crews assume that certain actions have been completed. Finally, it is proposed that if an unusual system configuration applies, there is an expectation that alerts that appear will be related to that system configuration. Three experimental hypotheses relating to these contexts were subjected to experimental research, the details of which are outlined in the following sections.

9.2 THE EXPERIMENTAL HYPOTHESES

9.2.1 THE ALERT/INDICATION CONTEXT HYPOTHESIS

The Alert/Indication Context Hypothesis proposes that in cases where a particular alert (which can be visual, verbal or system generated) or indication *usually* requires a particular response there will be a tendency to respond in the usual way even when a different response or no response is appropriate. This phenomenon was evident in the Charleston take off accident (NTSB, 2010c), where despite the captain requesting the flaps to be extended to the 20˚ setting, the first officer mistakenly set the flaps to the more frequently used 8˚setting. Whilst in the Charleston accident it appears neither pilot checked that the correct configuration had been achieved, in other instances pilots have actually made a verbal response stating they have seen the correct configuration despite evidence that the correct configuration was never set (See NASA ASRS Report 438691 at Appendix E). It is also evident from the literature that pilots become accustomed to performing the most usual response to an alert or indication, which has caused errors and omissions during instances requiring a less usual response (See the Charleston accident, NTSB, 2010c). This phenomenon has featured in several incidents involving TCAS manoeuvres required to avoid an inflight collision. The most usual category of TCAS alert and the one requiring the most urgent response is a *corrective* resolution advisory (RA) and always involves a modification to the aircraft's flightpath. The category of RA simulated in the alert/indication hypothesis experiment is an example of the less common *preventive* resolution advisory. Of the nine categories of RA outlined by Eurocontrol (2016) the preventive RA is the only category which requires no change of flight path. Although at low altitude and in high density airspace, preventive RAs are almost as common as corrective RAs, in less dense airspace above 5000 feet they are reported to be a very rare occurrence (Eurocontrol, 2010). Although technical advances may change this situation, it is likely that preventive RAs will retain a similar occurrence pattern. For the current research, the two important characteristics of preventive RAs are that they are comparatively rare occurrences and they require an untypical response. It is important to emphasise that this research was not intended to contribute specifically to existing knowledge related to TCAS, which is the subject of extensive ongoing research. In this study, the typicality of the alert and its response are the variables that provided experimental data, with corrective RAs and their required response being considered typical and preventive RAs and their required response as less typical.

The experimental hypothesis outlined below in paragraph 9.3.1 was that certain alerts/indications result in increased instances of incorrect responses. To test this hypothesis a comparison of pilots' reactions to simulated TCAS RAs that required a change of flight path with those requiring the current flight path to be maintained was conducted. This example was chosen because it was amenable to observational research with minimal experimental intervention. Because the flight crew procedure is one that is not normally varied by different airlines it was also possible to recruit participants from a wide range of backgrounds. In addition, the procedure is very prescriptive so a judgment as to whether it has been performed correctly is free of researcher subjectivity.

9.2.2 THE SITUATIONAL CONTEXT HYPOTHESIS

The situational context hypothesis proposes that certain situational contexts are predictive of certain related actions having been completed. This hypothesis addresses the type of SFP incident where for instance, a pilot forgets to extend the landing gear because the prevailing contextual cues predict that the landing gear would normally have been extended at that stage of the flight. The hypothesis is loosely based upon the Rescorla Wagner (1972) mathematical model of classical conditioning which states that individuals learn from the discrepancy between what they expect to happen and what actually happens, so if the landing gear is usually in an extended position when the flaps are at a particular position, the flap position is likely to achieve the status of a conditioned stimulus, with the landing gear position its conditioned response. Furthermore, the more frequently this association is made, the stronger the relationship between the two stimuli will become despite there being no actual association between the two. The current research examined how on occasions, repetitive situational contexts appear to provide the conditioned stimulus that predicts the status of a critical aircraft system such as the landing gear. Because pilots need to check that the landing gear is extended before landing, all aircraft have indicator lights to display the landing gear position; however, this research cites multiple instances of flight crews who have assumed the landing gear was extended when it was retracted. The landing gear down indication is designed to have a high level of associative strength with the landing gear position, and in most cases they are effective in ensuring the landing gear is extended. However, the reports examined for this study indicate that when flight crews forget to extend the landing gear it often occurs in a contextual situation involving an unusual flap and speed combination, which suggests that flap configuration also acts as a conditioned stimulus predictive of landing gear position. According to Rescorla and Wagner (1972) when two conditional stimuli (in this case, flap position and landing gear down indicators) simultaneously predict an outcome (in this case landing gear position) they compete to gain association with the outcome. Mackintosh (1975) presented research suggesting that in the situation described, the better predictor of the landing gear position would attract increased attention whilst the less perfect predictor would attract less attention. What if both stimuli were equally good predictors of landing gear position? In this case the salience of the stimulus appears to be relevant; however, the flaps and landing gear may vary in salience depending on the stage of the final approach. Final approaches can be diverse in nature but if ATC require accurate speeds to be flown, the flap position assumes far more salience than the landing gear position whereas if no speed control is in force, landing gear extension is likely to be the determinant of the deceleration point. It is not necessary to understand the complexities of energy management on final approach to understand that the salience of either the landing gear or the flaps can vary with contextual conditions. Multiple reports examined for this research indicate that the use of unusual flap/ landing gear configurations usually occur when pilots are required to fly a landing approach either faster or slower than they normally would or when they are displaced from their ideal descent profile close to the airport but at a distance where landing gear extension is inappropriate. The same reports also indicate that when flight crews fly with the landing gear retracted but with a flap configuration that is usually associated with the landing gear having previously been extended they may miss the cue to extend the landing gear.

The ASRS report below is from an Airbus A 319 captain:

While flying Bridge Visual to runway 28R in San Francisco approaching the bridge ATC assigned us to slow to 160 knots. I levelled off and slowed, concentrating on calling flaps as soon as they were available as we slowed. I did not call for the landing gear, I don't know why; I somehow just got focused on the flaps. We ended up in a flaps full configuration, on speed and glide path when we got the gear not down warning at 750 feet. (NASA, 2015a)

The reason that pilots in this contextual situation may fail to notice the inappropriate landing indication is probably a feature of their elevated workload in such contexts or due to Kamin Blocking, (Kamin, 1969) a phenomenon in which the first experienced stimulus in a compound of two or more conditioned stimuli tends to interfere with the second. It should not be forgotten that the manufacturer provides an indicator that is intended to provide the conditioned stimulus indicating that the landing gear is extended; however, if flying at a given speed or flap configuration becomes a more dominant predictor, then according to the Kamin Blocking paradigm it is to some extent predictable that the indicator or any warnings will be ignored.

9.2.3 THE SYSTEM CONFIGURATION CONTEXT HYPOTHESIS

The system configuration context hypothesis proposes that in instances where an unusual system configuration exists there will be a tendency for the flight crew to misattribute unrelated alerts to that unusual system configuration. One of the most recurrent manifestations of this phenomenon relates to flight crews who land with the landing gear retracted in a context involving an unusual flap configuration. This category of accident has involved large airliners including a Comet at Newcastle, a BAC One Eleven at Stansted (UK AIB, 1978), a DC9 at Houston (NTSB, 1997a), a Canadair Regional Jet at Barcelona (CIAIC, 2007), a Boeing 737 at Kaliningrad (Interstate Aviation Committee, 2009) and others, so there is extensive empirical evidence to support the hypothesis. As far as is known, no previous research has elaborated upon this phenomenon despite the evidence above spanning almost five decades. Other examples of misattribution errors include unsafe abbreviation of a checklist at Palmerston North, New Zealand (TAIC, 1995) and failure to perform a terrain warning escape manoeuvre at Jakarta (KNKT, 2012) both of which resulted in controlled flight into terrain (CFIT) accidents. The abbreviated checklist accident at Palmerston North occurred in the context of a previous defect with the landing gear that may have prompted the flight crew to continue an approach when according to the accident report it should have been discontinued. The ignored terrain warning at Jakarta which resulted in CFIT occurred in a context where the Russian captain possessed limited knowledge of the local Indonesian terrain and was receiving verbal guidance from someone with local knowledge which conflicted with the correct information in the terrain database. The report speculated that the reason the pilot failed to respond to numerous terrain warnings was that he perceived a problem with the terrain database, which was a clear case of misattribution. Another example of misattribution involved a DC9 flight crew who landed with the landing gear retracted at Houston Airport because the captain misattributed the associated warning horn to the late configuration change they were making rather than to the retracted status of the gear.

"The captain stated that he heard the horn sound momentarily and thought that it sounded because he put the flaps to 25 before the gear was down and locked." (NTSB, 1997a, p. 4)

The foregoing examples of the system configuration context hypothesis indicate that when flight crews adopt an unusual system configuration, whether as a consequence of a non-normal procedure or because a normal situation calls for it, there may be an increased likelihood of misattributing unrelated alerts to that system configuration.

9.3 THE CONTEXTUAL CUEING EXPERIMENTS

9.3.1 THE ALERT/INDICATION HYPOTHESIS EXPERIMENT

9.3.1.1 EXPERIMENT THREE RESULTS

Analysis of experiment three focussed upon the accuracy of the forty participants' responses to two categories of TCAS alerts, one of which was considered to be more typical than the other. The independent variable was represented by two levels of typicality. Because the occurrence literature indicated that corrective RAs were more frequent and required a less typical response than predictive RAs it was hypothesised that the former would result in more accurate responses than the latter; therefore the corrective RA was the control condition. The experimental condition was represented by the preventive RA. Accuracy data were collected for each participant and analysed in SPSS. Due to the low response values in some of the experimental conditions a Fisher's exact test of independence was chosen for this experiment. The results were very conclusive insofar as in the control condition, accuracy was 100% among the twenty participants. In the experimental condition eighteen of the twenty participants made one or more procedural error. This finding was so conclusive that it did not require statistical analysis but in the interest of completeness a more rigorous criterion for defining accuracy was chosen. The revised criterion for accuracy was that the pilot should have accurately followed the required TCAS flight path. In this revised experimental condition the aircraft was manoeuvred incorrectly in seven of the twenty instances, whereas in the control condition the flight path was flown correctly in all instances. A Fisher's exact test of independence was performed to examine the relationship between alert typicality and accuracy of response (Table 9.1). The relationship between these variables was significant $p<0.1$ single sided, indicating that the null hypothesis could be rejected; this means that the observed relationship between response accuracy and typicality of alert was not the result of chance. The bar chart at Figure 9.1 illustrates the results.

Table 9.1: Fisher's exact test of independence between alert typicality and accuracy of response

Chi Square Tests

	Value	Df	Asymp. Sig. (2 sided)	Exact Sig. (2 sided)	Exact Sig. (1 sided)
Pearson Chi Square	8.485[a]	1	.004		
Continuity Correction[b]	6.234	1	.013		
Likelihood Ratio	11.200	1	.001		
Fisher's Exact Test				.008	.004
Linear by Linear Association	8.273	1	.004		
N of Valid Cases	40				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.50.
b. Computed only for a 2x2 table

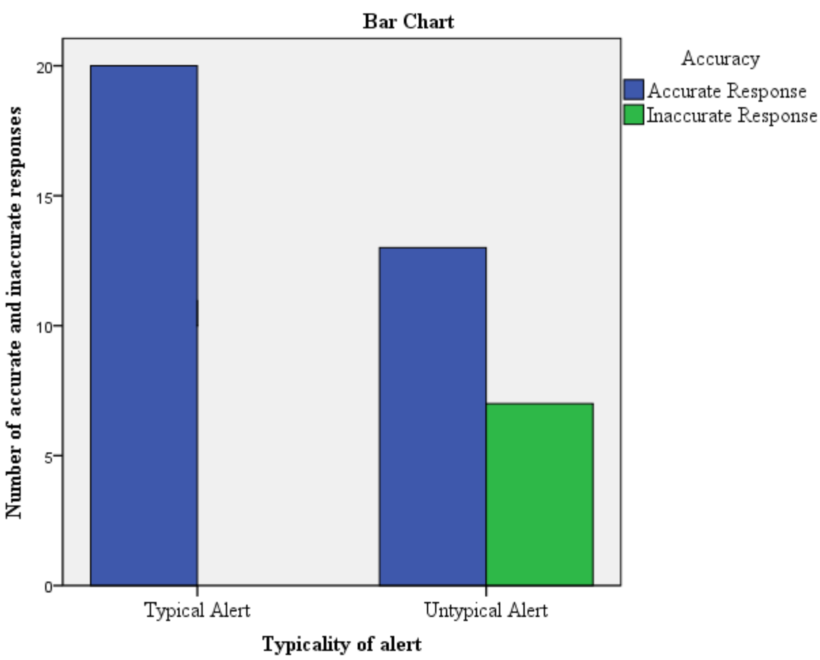


Figure 9.1: Typicality of alert versus accuracy of response.

9.3.1.2 EXPERIMENT THREE DISCUSSION

Experiment three provided experimental support for the hypothesis that an alert or warning that requires a response that is untypical of other similar alerts and warnings is more likely to attract an inaccurate response. Although the specifics of TCAS manoeuvres are interesting, it should once again be emphasised that this experiment was intended to test the more general hypothesis that some pilots subconsciously possess cognitions relating to certain categories of alert or indication that tend to favour the most typical category of alert or indication and the most usual response. Indications and alerts can take many forms; for instance the response to a verbal call to extend the flaps before taxiing is an alert that should not only result in selecting the required flap setting but checking that the flaps extend to that position. A search of the ASRS database for instances of incorrect flap settings was performed. Search terms included "wrong" and "flap(s)" and "incorrect". The search included all heavy public transport aircraft (referred to as Part 121 aircraft in ASRS) and was restricted to taxiing, takeoff and initial climb. Depending on the search term used, instances ranged from 95 to 52 of which 20 were directly relevant to this research. Of those 20 it was determined that 7 instances involved flight crews who had used a flap setting that they considered more usual than the one they should have used; this represents further support for the alert/indication hypothesis. Another repetitive instance of flight crews failing to perform a less typical response to an alert is during missed approaches in response to windshear on final approach; this topic is discussed later.

Cognitive psychology has long understood the role of prototypes in cognition. As early as the 1950s Eleanor Rosch highlighted the role that prototypicality can have upon cognitive judgments. Rosch (1975) found that members of a clearly recognisable prototype elicited faster RTs than for less prototypical examples. Also when participants were primed to expect a certain category they identified items from that category quicker than if priming had not taken place. She also found that when asked to name exemplars of various categories, her participants usually responded with highly prototypical ones. In just the same way that Rosch found that a robin and a penguin, although both birds, varied considerably in their prototypicality, so a TCAS manoeuvre that requires no actions other than to monitor what is happening, represents a poor prototype of such an alert. It is not difficult to identify other alerts or indications that are more or less prototypical; for instance, the occurrence literature included no instances of flight crews incorrectly responding to highly prototypical alert such as a fire warning or engine failure at low speed during takeoff, because all pilots know that such a warning requires a rejected takeoff (RTO) if it happens before decision speed. However, both abnormal acceleration and system failures on takeoff are among the criteria that Boeing and other aircraft manufacturers stipulate for a low speed (below 80 knots) RTO. The report relating to a serious takeoff occurrence at Melbourne (ATSB, 2009a) indicates that abnormal acceleration on takeoff is difficult to detect and a serious incident at Manchester UK (UK AAIB, 2008) suggests that even if it is detected, pilots are ill-equipped to make safe judgments in the face of such indications. Another particularly repetitive non-prototypical system failure is the failure of the autothrottle system to engage at the commencement of the takeoff roll. Catastrophic takeoff accidents at Romulus in 1987 (NTSB, 1988) and in Madrid in 2008(CIAIC, 2008) both involved flight crews who were unable to engage the autothrottle at the commencement of the takeoff and did not analyse the cause but continued the takeoff. An Air France Boeing 777 flight crew at Lagos were also unable to engage their autothrottle at the commencement of the takeoff and continued the take off to high speed until they realised that the aircraft would not fly (BEA, 2010). This very serious accident occurred because the flight crew had engaged the autopilot rather than the autothrottle. Whereas a competent flight crew would never choose to continue a takeoff whilst at low speed with, for example an engine fire, there are occasions when it is permissible to fly without a functioning autothrottle system because the throttles can be positioned manually, thus the latter's categorisation as a system failure becomes less clearly defined and therefore less prototypical. It may also be relevant that the less prototypical an indication or alert is, the less likely it is to be taught to flight crews in the simulator. The Buffalo accident report noted that it could not be determined whether the captain had seen a demonstration of the stall protection system (known as a stick pusher) on the type of aircraft he was flying (NTSB, 2010a, p. 88). A stall which results in the stick pusher activating, as was the case at Buffalo, is an extreme case and according to the report, instructors who would have taught the pilot in question had some discretion regarding the stall scenarios they needed to teach. There is a long history of pilots responding incorrectly to stick pusher events, including an accident involving a Trident at Staines in 1972 (UK AIB, 1973) so this is not a new problem. In both these accidents, separated by over three decades, it was likely that the pilots had not been trained for the unusual precise combination of indications they experienced; what is certain is that in neither case was a correct recovery performed. In fact in some cases a flight simulator is incapable of reproducing some examples of extreme mishandling, a factor noted in the Buffalo accident report (ibid., p. 38). It is also possible that the way pilots are taught in the simulator may influence their decisions. In flapless takeoff accidents at Madrid in 2008 (CIAIC, 2008) and Dallas in 1988 (NTSB, 1989) there is verbal evidence from the CVR that the pilots initially thought they were experiencing an engine failure despite the presence of an aural stall warning. This may be because whenever handling difficulties are experienced just after takeoff in the simulator it is usually the result of a simulated failed engine. Therefore the prototypical response to uncontrollability after takeoff is to initially assume an engine has failed. A recent accident at Bedford, Massachusetts (NTSB, 2015) involving a Gulfstream flight crew who unsuccessfully attempted a takeoff with the control locks engaged was an example of a very non-prototypical combination of indications (difficulty moving the throttles and an unusual indication relating to the rudder). Although either of these indications would qualify as a system failure, and would cast doubt over the ability to complete a safe takeoff, this flight crew's cognition of the situation permitted them to commence a takeoff in this unsafe condition. Another example of a very clearly defined category of manoeuvre is the go around, a procedure where the pilot discontinues an approach to landing, sometimes at low height. On almost all airliners this procedure calls for application of full power, the retraction of the flaps to an intermediate position, a check that the aircraft is climbing, followed by the retraction of the landing gear. This represents the prototype for a go around but in the case of windshear neither the flaps nor the landing gear should be retracted during the go around. So although the windshear go around is a go around, it lacks several of the defining features of a prototypical go around and so may be prone to be incorrectly performed, particularly if unexpected. Incidents and accidents involving flight crews who performed the prototypical go around procedure when a windshear escape go around manoeuvre was called for include the following: a DC 9 at Charlotte (NTSB, 1995), an Airbus in the USA (NASA, 2007), and a Boeing 737 at Melbourne (ATSB, 2010b). The Buffalo accident also highlights how pilots' behaviour can reflect the prototypes they hold in their cognitive system. The first officer at Buffalo (NTSB, 2010a) was responsible for a number of actions that certainly did not help the captain to recover the aircraft from the stall it had encountered. It was hypothesised in the accident report that she may have retracted the flaps because that represented the prototypical stall recovery she had been trained for in the weather conditions that had been experienced earlier in the flight (Ibid., p. 90). Another hypothesis was that she may have reverted to prototypical behaviour she had learnt on light aircraft prior to becoming an airline pilot (Ibid., p. 90). Less clear is the reason why the captain applied back pressure on the control column when stall recoveries prototypically require the nose to be lowered. On a normally flown final approach, if the approach has to be discontinued for most conceivable reasons the prototypical response is to climb the aircraft by raising the aircraft's nose. A stall warning on final approach is highly non-prototypical alert and the required response (lowering the aircraft nose) is very far removed from any prototypical response a pilot would expect to need to perform at that phase of the flight. The notion that the phase of flight might act as a cue for behaviour such as just described is elaborated upon in section 9.2.2 above and the subject of experimental research in section 9.3.9.

9.3.2 THE SYSTEM CONFIGURATION STATUS HYPOTHESIS

9.3.2.1 EXPERIMENT FOUR RESULTS

Analysis of experiment four focussed upon the accuracy of twenty four flight crews each consisting of two participants. Twelve flight crews were observed in the control condition which involved the introduction of a minor alert whilst taxiing. The control condition flight crews had no knowledge of any pre-existing condition that would cause an alert that could be ignored. In the experimental condition twelve flight crews were aware that their system configuration was predictive of the occurrence of an alert that could be ignored. The one tailed hypothesis was that the experimental condition participants would ignore an unrelated alert without analysis whilst those in the control condition would analyse any alert that occurred. The results were conclusive for the control group, who analysed the alert in all cases. Of the experimental group, eight flight crews ignored the alert and four correctly analysed the alert. Correct responses were identified as accurate and an incorrect response was identified as inaccurate for the purposes of analysis. For the purpose of analysis the control group was named "context unaware" and the experimental group was named "context aware". Accuracy data were collected for each flight crew and analysed in SPSS. Due to the low response values in some of the experimental conditions a Fisher's exact test of independence was chosen for this experiment. The Fisher's exact test of independence examined the relationship between context awareness/unawareness and accuracy of response. The relationship between these variables was significant *p<0.5* one tailed, indicating that the null hypothesis could be rejected and therefore the observed relationship between response accuracy and context awareness was not the result of chance. The descriptive statistics are shown in Table 9.2 below and graphically in Figure 9.2.

Table 9.2: Descriptive statistics for accuracy of response versus context awareness

Chi Square Tests

	Value	Df	Asymp. Sig. (2 sided)	Exact Sig. (2 sided)	Exact Sig. (1 sided)
Pearson Chi Square	4.800[a]	1	.028		
Continuity Correction[b]	2.700	1	.100		
Likelihood Ratio	6.351	1	.012		
Fisher's Exact Test				.093	.047
Linear by Linear Association	4.600	1	.032		
N of Valid Cases	24				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 2.00.
b. Computed only for a 2x2 table

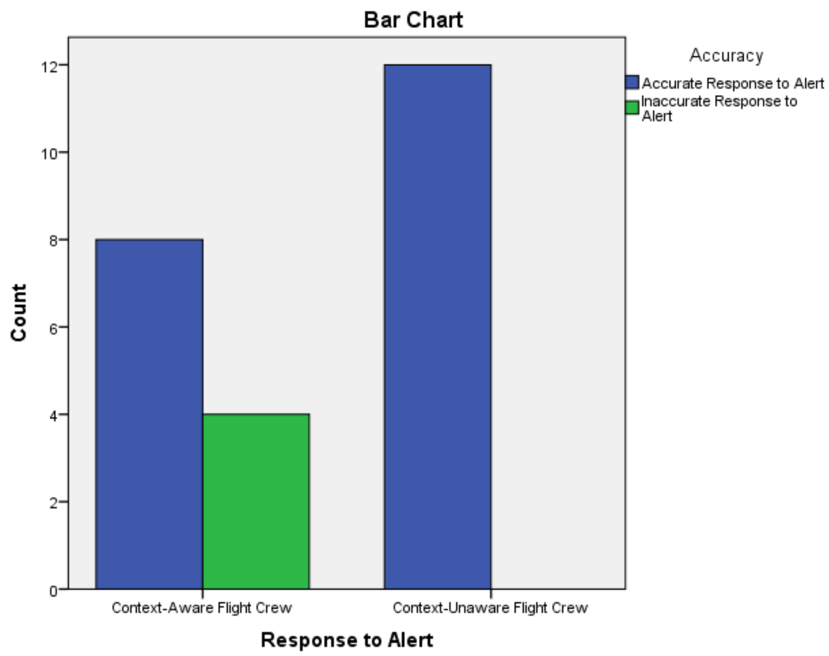


Figure 9.2: Context aware versus context unaware accuracy count.

9.3.2.2 EXPERIMENT FOUR DISCUSSION

The results of experiment four supported the hypothesis that knowledge of a pre-existing system status has the potential to significantly influence the accuracy of flight crew attributions. This finding has wide-ranging implications for aviation safety, for instance in the weighing of risk when implementing procedures that require the use of an untypical system status. The finding that so many of the participants made the error they did was not a surprise given evidence from accidents cited in this research in which the flight crew were aware of a pre-existing defect which may have affected their decisions. Of more interest is why they fail to predict and prepare for the risk in advance. This redirects the focus to risk perception, not only for pilots but also for those who design and implement procedures. Research into how airline managers perceive risk is very hard to find but as far as pilots are concerned it is unlikely that when they do something risky like abbreviating a checklist or ignoring a terrain warning that they are simply taking a chance; it is more likely that they have misperceived the risk associated with their prevailing context. Research by Hunter (2002) found only a weak relationship between risk tolerance and risk perception in pilots, supporting the notion that pilots sometimes fail to consider some of the more abstract consequences of operating in an unusual system configuration. Unusual system configurations come in many forms; in an accident at Palmerston North, New Zealand (TAIC, 1995) there was nothing unusual about the aircraft's systems prior to attempting to extend the landing gear but there was knowledge of previous problems with the landing gear and this is likely to have influenced the pilots' actions. Although it cannot be claimed with certainty that flight crew awareness of a pre-existing unusual configuration affecting the aircraft has resulted in poor decision making, there is evidence that they co-occur. Flapless takeoffs involving loss of control at Madrid (CIAIC, 2008) and Lanzarote (CIAIC, 2007b, p.85) both involved flight crews who were aware of an existing defect on their aircraft that may have made them more willing to accept an unusual indication. The current research contends that if they had not known about the existing defect it is inconceivable that they would not have attempted to diagnose what was causing the inconsistent systems indications they were experiencing. Serious safety occurrences also cluster around certain aircraft types; a disproportionate number of flapless takeoffs involve the type of airliner in the two occurrences cited above, whilst a disproportionate number of mishandled pressurisation occurrences affect another very common airliner. This suggests that both the design of both aircraft and their procedures may play a part in these types of errors. In some cases a non-normal checklist may direct a flight crew to adopt an unusual configuration, such as a non-normal flap configuration for landing, as was the case in the previously cited landing gear retracted accidents at Barcelona and Kaliningrad, whilst in other cases the unusual configuration may be linked to a company policy such as taxiing on one engine to save fuel (See NASA, 2015b). Although these are both legitimate reasons, it is important to emphasise that both these procedures carry risks. Evidence that even minor departures from a standard system configuration introduces risk is demonstrated in the extract below involving a flight crew flying a Boeing 737 over the Irish Sea who misattributed their high rate of cabin climb to the thrust setting they were using rather than the actual cause, which was that they had not configured the pressurisation system correctly:

ATC informed the aircraft that there was no speed restriction in effect… and as a result the flight crew increased the thrust…causing the aircraft to climb rapidly. They stated that the pressurization panel indications may have appeared normal to them because the aircraft was climbing rapidly. (AAIU, 2014)

This extract suggests that had the system configuration not been characterised by the use of the high thrust setting the flight crew might have completed a more thorough analysis of an unusual indication related to their cabin altitude. It should also be emphasised that this flight crew's hypothesis was not without foundation but what they did not appear to appreciate is that a minor change in system configuration could influence their decision making, probably without their conscious awareness. It is also noteworthy that this flight crew was able to describe contextual cueing in retrospect but did not consider it at the time; this highlights the utility of this research.

A recent fatal accident over the Java Sea (NTSC, 2014) involved an Airbus captain who disabled an essential system in flight resulting in a loss of control. During the investigation it emerged that the same captain had previously observed the same system configuration being legitimately used by an engineer during a rectification on the ground three days before the accident. On the accident flight the captain experienced the same malfunction that he had seen on the ground three days earlier and apparently assumed that the rectification process he had observed before was worth trying in the air.

The report concluded:

"The experience of the pilot in command witnessing problem solving by resetting the flight augmentation computer circuit breakers on 25 December 2014 might have influenced him to adopt the same procedure when confronted with the same problem"

(NTSC, 2015, p. 119)

The role of contextual cueing is that if this pilot had not been exposed previously to this system configuration he would not have had any reason to deviate from the approved procedure for the malfunction he experienced, and the flight could have continued safely albeit in a slightly degraded condition. Unusual configurations are not confined to aircraft systems; they can also apply to the wider aspects of the aviation safety system such as airport layouts. Discussions between the FCMs involved in a wrong runway takeoff at Lexington (NTSB, 2007a, p. 3) indicated that they were aware that the lighting on the airport was not in a standard configuration. Although there was a verbal expression of uncertainty from one of the pilots as the takeoff was commenced, their knowledge of the status of the lighting may have resulted in them being more tolerant of the unusual visual scene as they commenced their takeoff. Similarly, there is evidence in the report of the serious takeoff incident at St Kitts (UK AAIB, 2010a, p. 8) that the pilots were uneasy about the visual configuration that confronted them before they commenced their takeoff. Once again, it is conceivable that their tolerance of the unusual was cued by the knowledge that they were using a high flap setting that they associated with shorter than usual runways and therefore expected to be confronted with a runway which appeared shorter than usual. An expectation of a shorter runway surface than usual was also offered as an explanation by the captain involved in an attempted taxiway takeoff at Oslo (AIBN, 2006, p. 3) cited earlier in this thesis. The contention is that in each of these instances the flight crew were influenced by an unusual system configuration unrelated directly to the aircraft. The general premise of the system status context hypothesis is that there is a significant chance that flight crews might be influenced to misattribute causes of relevant factors affecting flight safety because of preconceptions they hold, some of which may be the result of implicit learning.

9.3.3 THE SITUATIONAL CONTEXT CUEING RESEARCH

This research elaborated upon the theme of prototypicality by examining the extent to which repetitive situational contexts might influence flight crews to make errors and omissions. Unlike the previous two hypotheses relating to contextual cueing, the experimental method was not appropriate. In this research a detailed literature review provided qualitative data. Because aviation has a well-developed occurrence reporting system in many countries, it is possible to identify from reports, repetitive contextual situations that have prevailed in advance of an incident or accident. However, because these instances are usually few in numbers it is difficult to draw conclusions from much of the data. For instance, there are several documented instances of flight crews attempting (and in some cases succeeding) to take off from a taxiway or closed runway in a situational context involving earlier than usual receipt of take-off clearance (e.g. AIBN, 2006:2010). Although this represents a recurrent pattern, this research could only locate very few documented cases worldwide, so the sample size would be too small to claim more than a suspicion that the situational context was implicated. In order to examine the role of situational context, a larger sample was needed but thankfully most relevant phenomena are similarly affected with very small numbers of instances. A detailed review of the occurrence literature revealed that in addition to the instances of landing gear retracted landings outlined in previous sections, there were a significant number of instances where a flight crew had apparently forgotten to extend the landing gear and the error was only mitigated by the aircraft's warning systems. This was the category of occurrence examined in this research. Although the data relating to such occurrences are interesting, the primary objective of this section was to establish whether a more general relationship existed between situational context and errors and omissions.

9.3.3.1 RESULTS OF THE SITUATIONAL CONTEXT CUEING RESEARCH

This research found twenty five documented instances of Boeing and Airbus airliners descending on final approach to between 1000 feet and as low as 200 feet with the landing gear retracted. No normal operations require flight crews to fly a final approach with the landing gear retracted below 1000 feet so it is reasonable to assume that during normal operations any flight crew descending an aircraft below 1000 feet with the landing gear retracted falsely believed that the landing gear had been previously extended. The next section describes the contextual cues that were available to the flight crews just before their omission was noticed.

PREVAILING CUES BELOW 1000 FEET

This section outlines the features of the flight crews' situational environment that might be implicated in their omission. There were a few dominant features; firstly, all except two of the dataset flight crews were flying visually, meaning they could either see the runway or had good general visibility and an expectation that they would continue visually. None of the dataset flight crews had completed the necessary checklists. They were all appropriately positioned vertically and horizontally. Two instances involved pilots who intentionally flew slightly above the glideslope to avoid wake from a preceding aircraft. All of the flight crews had been cleared by ATC for their current phase of flight.

SPEED AT 1000 FEET

This research found that 90% of the dataset were at or close to their target speed. This probably indicates that the pilot believed that the aircraft was in the landing configuration. If the pilot knew there was further deceleration required it is unlikely that the speed would be constant at this late stage of the approach.

THRUST SETTING AT 1000 FEET

This research found that 75% of the dataset aircraft were likely using more than idle thrust at 1000 feet. This statistic is a conservative estimate because there is considerable evidence that up to 90% of the dataset flight crews may have been using thrust at 1000 feet. All of the Boeings would have required more than idle thrust to fly at the speed and flap configuration that prevailed. In the case of the Airbuses it was more difficult to determine because Boeings always use either of two landing flap setting for normal landings (which require significant thrust to be used) whereas Airbus flight crews are more likely to use an intermediate flap setting for landing (usually Configuration 3) which requires a low thrust setting even with the landing gear extended. Nonetheless, there was sufficient evidence in the reports to suggest that at least 75% were not at idle thrust at 1000 feet.

FLAP CONFIGURATION AT 1000 FEET

This research found that 60% of the dataset flight crews were not at their intended landing flap setting at 1000 feet. None of the Boeing flight crews in the dataset were configured at their planned landing flap configuration at 1000 feet. Five of the eight Boeing flight crews who were not at their landing flap configuration at 1000 feet were complying with a speed restriction imposed by ATC and one was flying in accordance with a company noise abatement procedure. It was unclear why the other two flight crews had not selected their landing flap configuration. Although three Airbus flight crews mentioned that planning to land with Configuration 3 rather than Configuration Full may have been implicated in their failure to configure the aircraft in time, there was no supporting evidence in the data.

After detailed reading of the relevant reports it can be concluded that if the landing gear is not extended by 1000 feet the absence of a landing gear down indication is not sufficient stimulus to alert the pilots to their error. Given that the criteria for continuing an approach below 1000 feet in most airlines centre upon the thrust setting, the flap setting and the speed, these were the focus of this study. An incorrect speed did not appear to provide a reliable cue that something was amiss. All but two of the dataset flight crews were very likely to have been stabilised (not accelerating or decelerating) at the speed they had intended to fly, which was not necessarily the planned final approach speed. This supports the notion that they had forgotten that their speed was incorrect until alerted by a warning. Thrust was rarely at idle, so there might have been some aural stimulus from engine noise that approximated a normal approach noise level.

Although there was an equal distribution of flight crews who had selected their planned flap setting by 1000 feet and those who had not, it was evident that the majority of flight crews who had not selected their planned landing flap setting were flying Boeings. This is likely to be partly because some Airbus flight crews fly their intermediate approach at Configuration 3 and continue to a landing in this configuration. Boeings are unable to do this and as a consequence, their intermediate approach flap setting always needs to be increased for landing. The problem for Boeing pilots appears to be related to the use of Flaps 20 (or in one case Flaps 15) with the landing gear retracted. Although the sample size was small, if Boeing flight crews were considered in isolation, the effect of using Flaps 20 with gear retracted would be very significant. In none of the dataset instances had the checklists been completed; this is particularly surprising because some of the aircraft in the dataset (Boeing 777s) have electronic checklists that will not allow such an omission. Two pilots reported that they remembered starting a checklist but not completing it.

9.3.3.2 DISCUSSION OF THE SITUATIONAL CONTEXT CUEING RESEARCH

This section offers some explanations for the flight crews' failure to notice their omission,

WHY WAS THE ABSENCE OF THE LANDING GEAR INDICATION MISSED?

There are several potential reasons why a visual stimulus like the landing gear indicator might not attract the flight crew's attention. Firstly, it may be that it is not considered salient at 1000 feet because in the normal course of events it is unnecessary to check it because the landing gear is almost without exception, extended. Research by Raymond & O'Brien (2009) indicates that allocation of attention varies with motivational salience in conditions of both high and low attentional demands. Their research also indicated that the decision to attend or otherwise to a visual stimulus was not only influenced by current demands upon attention but also by a prediction of the value of attending to that stimulus, in other words the probability of achieving a positive outcome by allocating attention to the stimulus. Neurobiological support for this finding is found in studies indicating that value prediction influences visual cortex activity in rats (Shuler & Bear, 2006) and in lateral intraparietal cortex in monkeys, an area associated with eye movements (Bendiksby & Platt, 2006). More recent research indicates that a neural mechanism in the basal forebrain of rats is selectively activated by motivationally salient stimuli independently and is capable of affecting the activity of widespread cortical circuits (Lin & Nicolelis, 2008); this mechanism appears to be akin to mechanisms thought to mediate top down control in humans (Raymond & O'Brien, 2009). In addition to its salience, to capture attention it would seem to be a prerequisite that the stimulus be visible. In fact, even absent stimuli are processed by the brain; according to Chun and Marois (2002), even when a visual stimulus is absent, neural mechanisms prepare for upcoming visual events, so the brain is already predicting what will be seen and where it will be located. It might be expected that the brain would identify that the stimulus was absent and that this information would contribute to top down processing. Rensink et al., (1996) examined change blindness and found that introducing a blank stimulus between alternating displays of an original and a modified scene resulted in a failure of perception whereby changes to the scene were not noticed so readily. Rensink's research although different from the attentional task in the flight deck, does provide support for the idea that an absent stimulus can be attended to and its absence ignored in certain conditions.

WHY WAS THE ABSENCE OF NOISE NOT NOTICED?

Just before a normal landing there are two sources of increased noise on the flight deck, namely that from the increased engine thrust and that from the airflow over the landing gear. Both these sources of noise are noticeable from the flight deck, as is the sound of landing gear extension, and there is little doubt that flight crews become accustomed to such auditory stimuli. For many flight crews the ability to react to auditory stimuli of the type just outlined may be restricted by the specifics of the equipment in use. Active noise reduction (ANR) headsets are designed to reduce the influence of external noise on the flight deck and are typically used on both ears in conjunction with the intercom, in which case it is very unlikely that engine or landing gear noise would capture the attention. Another common practice is to use one headset earpiece (usually the outboard) to listen to ATC and the other ear to listen to the other pilot and noises in the flight deck. This process of using individual ears for different stimuli is known as dichotic listening. A dichotic listening experiment by Cherry et al. (1953) found that although his participants could alternate their listening between ears, when they needed to concentrate upon one particular channel very little information processing of the unattended channel took place. A phenomenon known as the phonemic restoration effect may also play a part in the failure to notice absent auditory stimuli; in this perceptual phenomenon under certain conditions, sounds actually missing from a speech signal can be restored by the brain and may appear to be heard. Numerous studies have also shown strong effects of top-down attention on auditory processing in active listening; for example, studies that have shown that human auditory cortex is activated in the complete absence of any real world acoustic stimulation, when there is simply an inner expectation of sound (Hughes, et al., 2001: Raij, et al., 1997: Wu, et al., 2007). Experimental research which monitored brain activity during the short, quiet interlude of musical transitions identified activity in a ventral fronto temporal network associated with detecting salient events. Particularly relevant is research by Haslinger et al. (2005) who found that professional pianists who viewed sequences of silent piano playing were subject to activation of auditory areas of the brain in a way not present in naïve participants. These results were interpreted as an indication of specialization of a fronto-temporal network in the brain due to frequent observation which, it has been suggested, is implicated in the linking of visual and auditory perception to motor performance. These studies provide considerable evidence that an auditory stimulus associated with a salient visual stimulus can be imagined even when absent, so the absence of sounds related to landing gear extension is unlikely to be a reliable cue that the landing gear remains retracted.

WHY WAS THE INCORRECT SPEED NOT NOTICED?

It is not unreasonable to question the emphasis in this research, on speed as a factor in these occurrences given that there is no obvious link between flying at the wrong speed and forgetting to extend the landing gear. The link is quite complex but is caused by the relationship between speed and flap setting; unusual flap settings have been a recurrent feature of landing gear retracted landing accidents for decades and unusual flap settings are usually a consequence of flying at an unusual speed for the phase of flight. To support this contention Figure 9.3 shows the flight parameters of a US Air Boeing 767 which came very close to landing with the landing gear retracted at Gatwick in 2006 (UK AAIB, 2006a). The pilot's testimony was critical of the "unnecessary speed assignments" he had experienced during the approach. The traces at the top of the graph show that the aircraft was properly aligned both vertically and laterally for the intended landing and that some thrust was applied. At the bottom of the graph the red trace labelled "A" shows that the aircraft was flown at a constant 160 knots with flaps position 20 until the gear doors open in response to a "gear disagree" warning at approximately 500 feet; this is illustrated by the intersection between the warnings (labelled B) and the radio altitude trace (labelled C) and highlighted with yellow arrows.

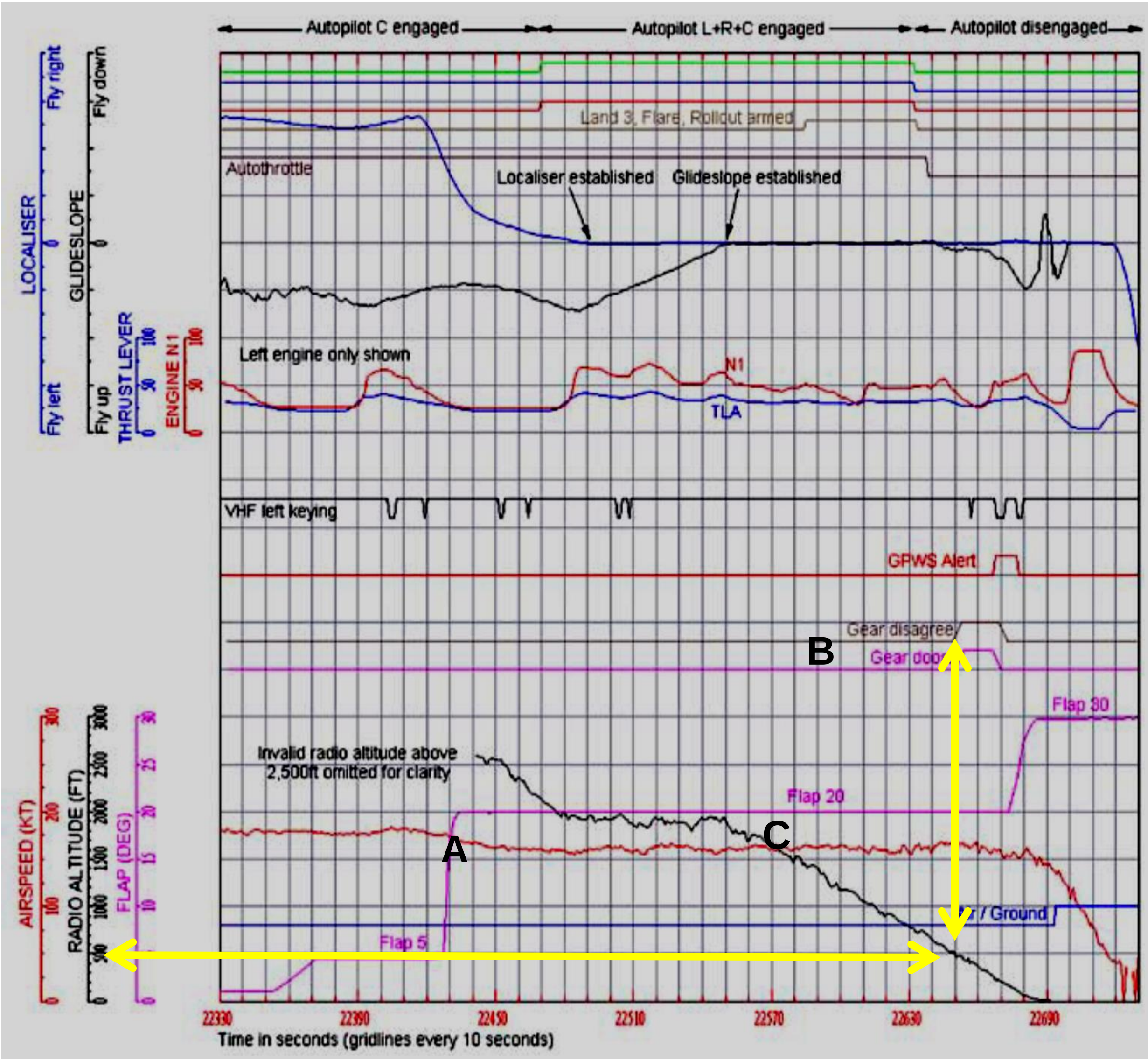


Figure 9.3: The flight parameters of a Boeing 767 which was the subject of a serious incident report (source UK AAIB, 2006a)

Compelling evidence that flight crews do not monitor their speed as much as they should was presented in the report into a stalling accident involving a Turkish Boeing 737 at Amsterdam. The associated report highlighted the role of the speed tape on the primary flight display (PFD). The report noted (Dutch Safety Board, 2010, p .64-65) that “although the speedtape on the PFD has a couple of built in indicators to accentuate speed, research in the past has demonstrated that the speedtape is not a good basis for speed observations at a glance”. The round format of earlier speed instruments gave crews the ability to distinguish speed deviations and to immediately recognize them from the position of the indicator, without a digital value first having to be read and processed mentally. Thus speed awareness has become a mental processing task rather than a visual recognition task as it was on previous round dial instruments. The Dutch report concluded that even in the presence of readily visible speed cues the flight crew did not recognize the unintentional decrease in airspeed.

The research cited in the previous paragraphs describes why the contextual cues present at 1000 feet are unlikely to be a reliable predictor of landing gear status. Given the evidence that if a flight crew reach 1000 feet with the landing gear retracted they are relying on their last line of defence (the aircraft’s warning systems) it is essential to consider the contextual conditions that give rise to omitting to extend the landing gear at the appropriate position.

WHAT CONDITIONS FAVOUR OMITTING TO EXTEND THE LANDING GEAR?

THE ROLE OF NON NORMAL OPERATIONS

Although non-normal operations were excluded from the dataset, the analysis of the ASRS database included several occurrences that bore some of the hallmarks of accidents at Barcelona in 2007, Kaliningrad in 2008 and Houston in 1996. In particular, each of the accident flight crews had experienced difficulty extending their aircraft’s flaps but had no problem that would have affected landing gear extension. In all of these accidents the flight crews also ignored warnings that the landing gear was retracted. Training flights or flights where the flight crew had chosen to use an unusual flap configuration for landing were also empirically linked to landing gear retracted accidents (See UK AAIB, 2010d).

SLOWING DOWN EARLY AND DELAYING LANDING GEAR EXTENSION

Being requested to slow down early by ATC or slowing down early because of a non-normal procedure appears to expose flight crews to the risk of forgetting the landing gear. On many heavy airliners it is necessary to progressively increase the flap extension with decreasing speed in order to maintain a safe margin above a stall. If such a deceleration is called for (for instance by ATC) when the aircraft is still a long way from the airport an unusually high flap setting may be needed. During training, the point at which the landing gear is extended is clearly defined but in the real world flight crews may choose to delay landing gear extension. This can result in the aircraft being flown with a flap setting which is predictive of the landing gear having been extended. On many of the Boeings in the dataset an early deceleration on approach often results in flying at flaps 20 with the landing gear retracted. Although there is no technical objection to flying at flaps 20 with the landing gear retracted, during initial and recurrent training, flaps 20 is usually associated with the landing gear being in the extended position. The flight crew cited earlier who nearly landed with the landing gear up at Gatwick were using this landing gear and flap combination, as were all but one of the Boeing flight crews in the dataset, so there is supporting evidence for this risk factor. The data indicated that the relationship between flap position and landing gear status was less predictive on the Airbus than on the Boeing, although there was evidence in the narratives (See page 371) that some pilots attributed their omission in part to flying at configuration 3 with the landing gear retracted. This means that for some pilots configuration 3 is predictive of the landing gear being extended; it does however, appear to be a weaker effect than the flaps 20/gear up configuration on the Boeing.

The effect of delaying landing gear extension could not be ignored in the dataset. At least seven flight crews had consciously chosen to delay landing gear extension because they were slowing down further from touchdown than usual. It appears that once flaps are extended to flaps 20 on a Boeing or configuration 3 on an Airbus some flight crews lose their cue to extend the landing gear. For these flight crews landing gear extension has become a prospective memory task, meaning they need to recall their intention to complete the action at some future point. Research by Anderson & Douglass (2001) indicated that their participants appeared not to engage in cognitively costly advance preparation when they suspended a goal, and that their retrieval was slow and in some cases completely ineffective if the goal had been suspended for an extended period. This may explain instances where a flight crew extended the flaps early and sometime later forgot to extend the landing gear. Notably, several of the flight crews involved were able to identify the precursor conditions in retrospect but failed to mitigate the risk in advance. Several instances in the dataset involved a distraction occurring after the goal of extending the landing gear had been suspended to some point in the future. Distractions vary in the level to which they displace memory of a suspended activity; avoiding wake turbulence by flying a higher than usual descent path, decisions related to weather and fuel and late runway changes were all distractions in the dataset that were able to displace memory of the suspended action. There were very few instances in the dataset where no distraction was present. According to Altmann and Trafton (2002) there is a window of opportunity just before the current goal is suspended when it is possible to strengthen the goals and encoding cues. However, the narratives examined in this study indicated that flap extension often occurred concurrently with a requirement to reduce speed so the opportunity to expend time and cognitive effort was probably limited. When the time comes to retrieve the suspended goal from memory it must receive priming from contextual cues in order to boost its activation level above that of other competing goals. Associative priming relies upon links being formed between the target goal and cues that would have been associated with the context when the goal was suspended. In this case the primary retrieval cue is drawn from long term knowledge about the task and is thus part of the internal mental context held by the pilot. Information from previous associations will only be an effective retrieval strategy if the associative links are reliable, that is if the flap setting is always a predictor of the landing gear position. From the dataset it can be speculated that the associative linkage between flap setting and landing gear position vary in their strength between the two types of aircraft. Selecting flaps 20 early with the landing gear retracted represented the context for error in Boeing flight crews. For Airbus flight crews although configuration 3 was not a reliable predictor of landing gear position, it is possible that because it can be used for both approach or landing, seeing the flaps at configuration 3 could cue a pilot to believe the aircraft was configured for landing. It is clear from the dataset that the contextual cues available to these pilots at 1000 feet were not sufficient to alert them to the fact that the landing gear remained retracted.

PLANNING TO USE A REDUCED FLAP SETTING FOR LANDING

Using a reduced flap setting for landing reduces noise, saves fuel and increases traffic flow, so it has become common practice in recent years. The Boeing and Airbus differ slightly in the detail in this respect. During normal procedure landings Boeings always land with a flap setting that is exclusively intended for landing whereas the Airbus can make normal landings with a flap setting exclusively intended for landing (configuration full) or with a setting that is used as an intermediate position but can also be used for landing (configuration 3). There were four documented instances (2 Airbuses and 2 Boeings) of flight crews who were using a reduced flap setting as a consequence of a non-normal procedure who forgot to extend the landing gear. Because there was such a low incidence of such occurrences they were excluded from the statistical analysis but there is considerable evidence from previously cited accidents that landing gear retracted occurrences are empirically related to non-normal situations unrelated to the landing gear. On the Airbus it is conceivable that utilising configuration 3 for both intermediate approach and for landing may make this setting more prone to be accepted as a landing setting in instances where this is not the case; this was mentioned by three pilots in the dataset. Of the thirteen aircraft in the dataset that were still at an intermediate flap setting at 1000 feet, five were Airbuses and eight were Boeings. Of the five Airbuses, three had planned to use configuration 3 for landing and were therefore at their intended landing flap configuration. None of the Boeings were at their planned flap configuration for landing. Six of the eight Boeings were in a Flaps 20/ gear up configuration, making this the most common configuration associated with forgetting to extend the landing gear.

THE ROLE OF RESTRICTIONS ON SPEED

Few of the documented cases of pilots failing to extend the landing gear occurred in situations where the pilots were free from some constraint upon their flap configuration. The most common error involved unintentionally remaining in an intermediate flap configuration below 1000 feet after some kind of distraction. This co-occurred with one or more of the following contextual conditions:

- A request from ATC to maintain a higher than normal speed to a late stage in the approach.
- A standing procedure to retain a higher than normal speed until a late stage in the approach.
- A company procedure that called for delayed flap extension in the interests of fuel saving.
- A company procedure that called for a reduced flap setting for landing.
- A requirement to slow down at a distance from touchdown where landing gear extension would be unusual.
- A non-normal procedure requiring an unusual flap configuration.

- Flying faster or slower than normal on final approach emerged as the most recurrent factor in the dataset. Defining *normal* is difficult because there are differing perspectives. It would be reasonable to define any procedure that conflicts with the initial and recurrent training pilots receive as a departure from normal but many would disagree. Pilots do not receive simulator training in the types of approaches that featured in the dataset such as delaying landing gear extension during a non-normal approach or joining a glideslope from above, but they are expected to do all these manoeuvres without any formal training. So this research contends that any procedure that invokes a context that has resulted in error should be highlighted. Flying at an ad hoc speed on final approach is just one such precursor to the contexts that have been found to promote error. The cross-tabulation statistics in Table 9.3 indicate that based upon the dataset instances, the relationship between speed control being applied on final approach and arriving at 1000 feet in the wrong configuration is statistically significant $p<0.05$ one-tailed.

Table 9.3: Speed Constraint * Flap Configuration at 1000 feet Cross tabulation
Count

		Flap Configuration at 1000 feet Planned Landing Flap	Intermediate Flap	Total
Speed Constraint	Speed Control Applied	3	9	12
	No Speed Control Applied	6	2	8
Total		9	11	20

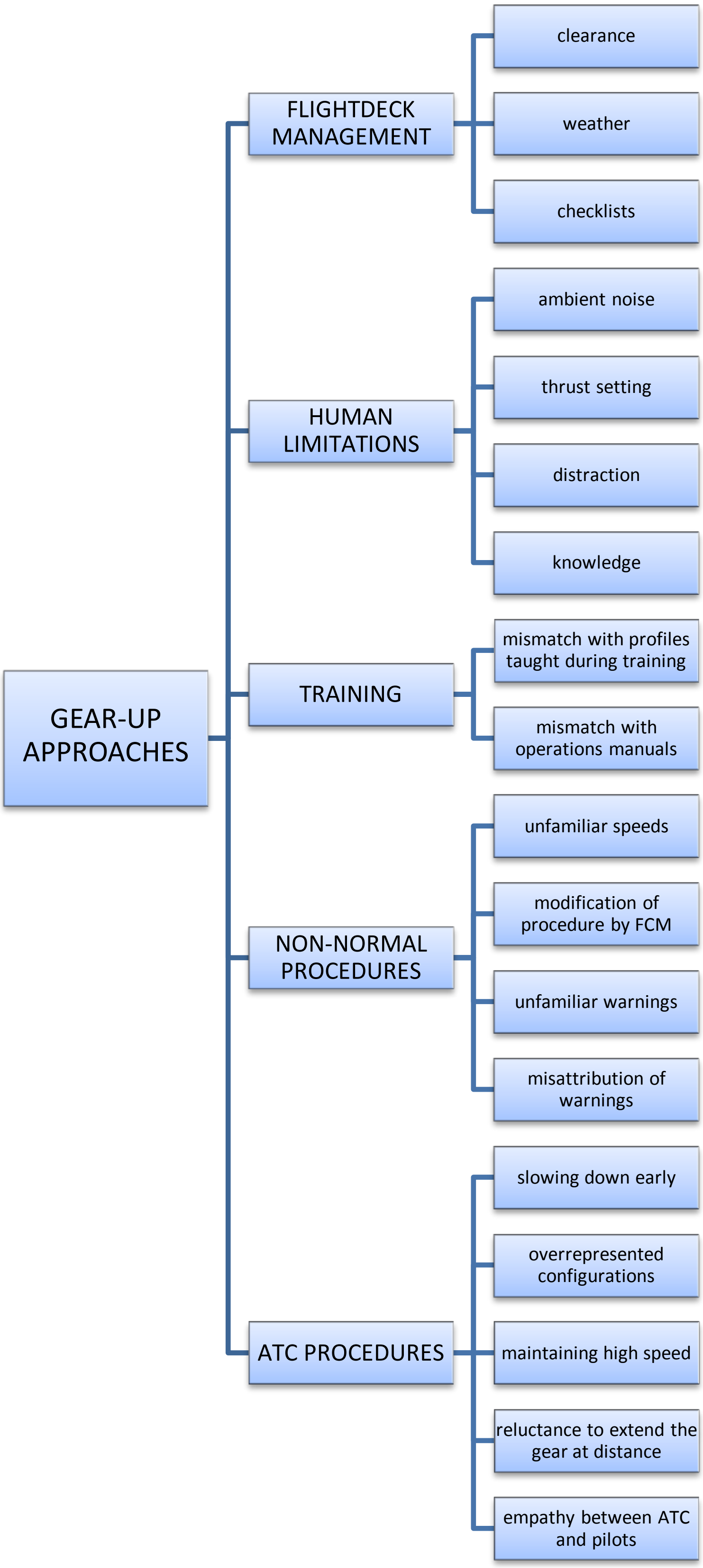
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.848[a]	1	.028		
Continuity Correction[b]	3.039	1	.081		
Likelihood Ratio	5.032	1	.025		
Fisher's Exact Test				.065	.040
Linear-by-Linear Association	4.606	1	.032		
N of Valid Cases	20				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.60.
b. Computed only for a 2x2 table

Figure 9.4 is the gear up approach taxonomy developed from the situational context hypothesis research. This is followed by a description of the characteristics of each factor.

Figure 9.4: The gear up approach taxonomy



FLIGHT DECK MANAGEMENT

- CLEARANCE: All the FCMs in the dataset were complying with their ATC clearance.
- WEATHER: Most of the FCMs in the dataset were flying visually.
- CHECKLISTS: None of the FCMs in the dataset had completed the landing checklist.

HUMAN LIMITATIONS

- AMBIENT NOISE: The absence of noise from the extended gear did not alert the dataset FCMs to their omission.
- THRUST SETTING: The reduced thrust required in the gear up configuration did not alert the dataset FCMs to their omission.
- DISTRACTION: Where FCMs deferred the decision to extend the gear the presence of a distraction could cause them to forget they had deferred gear extension. FCMs did not appear to take steps to mitigate the risk of deferring gear extension in advance despite recognising the risk in retrospect.
- KNOWLEDGE: Interviews with pilots suggest they are generally uninformed about the risks of prospective-memory tasks.

TRAINING

- MISMATCH WITH OPERATIONS MANUALS: The types of flap/gear configurations evident in some of the dataset occurrences are not outlined in the aircraft training manuals. For instance, low drag non-normal or non-precision approaches are not outlined. Manufacturers and operators should ensure their documented procedures reflect the procedures that actually occur in real life.

- MISMATCH WITH PROFILES TAUGHT DURING TRAINING: The classic flight profiles taught during initial conversion bear little resemblance to some of the profiles pilots need to fly in everyday operations. During initial and recurrent training an association between large flap settings and gear extension is forged. Training should reflect the needs of the real world better than is currently the case.

NON NORMAL PROCEDURES

- UNFAMILIAR SPEEDS: Non-normal procedures require pilots to slow down early in some cases and to fly faster than usual in others.
- MODIFICATION OF PROCEDURE BY FCMs: No non-normal flap procedures recommend delaying gear extension but there is evidence in the reports that some pilots choose to do so.
- UNFAMILIAR WARNINGS: Non-normal procedures involving flaps frequently generate warnings that pilots rarely encounter.
- MISATTRIBUTION OF WARNINGS: In the past, during both revenue and training flights, pilots have misattributed the warnings mentioned above and landed with the gear retracted.

ATC PROCEDURES

- SLOWING DOWN EARLY: ATC sometimes require pilots to slow down earlier than normal; on some aircraft this requires a higher than normal flap setting for that position in space. During training, higher flap settings are associated with the gear down configuration.

- OVERREPRESENTED CONFIGURATIONS: Boeing 757/767/777 pilots use gear up/flaps 20 when they need to slow down early; this configuration has been evident in several gear up incidents (See UK AAIB, 2006a). Several Airbus pilots commented in ASRS reports that aspects of procedures involving landing with configuration 3 rather than full flaps had provided the context for an error, although this was not a highly recurrent narrative. The extracts below are all pilot narratives relating to unstable approaches in Airbus aircraft:

Do not go beyond flaps two before the gear is down when landing flaps three. (NASA, 2014)

"Even though we had briefed using flaps full for landing, the aircraft can be landed at flaps three" (NASA, 2003a)

"Usually I select gear down with flaps three" (NASA, 1993)

- MAINTAINING HIGH SPEED: ATC sometimes require pilots to maintain a higher than desirable speed to a position close to the runway. This may require pilots to stay at a lower than normal flap setting later than is normal for that position in space. Some heavier aircraft will require a higher than normal flap setting early in the approach and a lower than normal setting as they approach the runway.

- RELUCTANCE TO EXTEND THE GEAR AT DISTANCE: Pilots are reluctant to extend the landing gear when they are considerable distance from the runway, resulting in unusual flap/gear configurations if they need to slow down earlier than usual.

- EMPATHY BETWEEN ATC AND PILOTS: Operators and airport authorities favour high speed on final approach whereas pilots are constrained by stable approach criteria which may be incompatible with ATC requirements. At Heathrow Airport there is a plan to reduce spacing between aircraft on final approach when the headwind is strongest; these are just the conditions when many pilots would prefer more spacing in order to avoid a potential last-minute go around in turbulent conditions. It is unlikely that air traffic controllers understand the intricacies of final approach energy management on the various different aircraft they control.

9.3.4 LIMITATIONS OF THE CONTEXTUAL CUEING RESEARCH

The system status and alert/indication experiments were complicated and expensive to run so they inevitably involved fewer participants than would have been desirable. Also the opportunities to approach participants were fewer so their recruitment was less random than would have been desired. Ethical considerations meant that almost no personal information about the participants was collected; however, these data were irrelevant to the research objective. The two simulated scenarios were highly simplified and effective but the statistical tests only measured independence so it is not possible to claim that causation exists on the basis of the results. It could be argued that the control conditions in both the experiments represented situations where it would be very unusual for a flight crew not to behave in the way they did. The experimental condition was examining very untypical flight crew behaviour so it would have been unrealistic to use a control condition that did not reflect the difference between control and experimental conditions. The statically significant results also align with some of the evidence from the occurrence literature.

The situational-context study was originally intended to be an experimental study as well but it proved methodologically impossible. An alternative approach was to use self-reports as qualitative data. Self-reports, although widely used in the aviation context and elsewhere, do have their limitations; for example people often respond in such a way that presents them in a more favourable light even if these responses do not reflect how they actually behaved, this is known as “socially desirable responding” (Paulhus, 1991). In general terms, if there was any doubt about the relevance or precision of a report it was excluded. There were also some very significant incidents for which no data were available, including a fully serviceable Boeing 747 which landed with the landing gear retracted at Islamabad in 1986. Sometimes there was clear evidence that an accident had occurred but no official report, as in the case of a Comet that landed with the landing gear up in Newcastle in 1970. Inevitably there were confounding factors such as fatigue, air traffic control requirements and substandard technique. Training flights were disproportionately represented in flapless/gear up landing reports[xv], probably because flapless landings, whilst often practiced during training, are a rare occurrence in day to day operations. This dataset, whilst not claiming to include all instances of approaches flown with the landing gear retracted near the ground worldwide, is considered representative of the phenomenon in general. In common with the ASRS database from which much of the data originated, the data presented in this thesis probably represent a low estimate of instances, with the true incidence worldwide probably considerably higher. Identifying the point in the approach at which it could be stated with some certainty that the landing gear extension had been forgotten was a subjective decision. On the basis that most airlines require the landing configuration to be achieved by 1000 feet, this was the figure chosen for this study. The conditions that prevailed at that point were not always explicitly stated in the reports so it was necessary to identify the important contextual features present in the most detailed reports and attempt to deduce missing data from the less detailed ones. For instance, it emerged quite early on that the role of air traffic control speed constraints was frequently mentioned in the more detailed reports. In cases where it was suspected that speed constraints might have been a factor but were not mentioned, reference was made to the published procedures for the airport concerned. For instance, it is highly improbable that an aircraft inbound to a busy airport like Heathrow would have no speed restriction on final approach even if it was not mentioned in the report. In the final dataset it was not necessary to make such inferences so the data therein are considered to be as accurate as possible. Several reporters commented that they had been distracted at the point in the approach where they normally extend the landing gear but none clearly defined that point. It was clearly before 1000 feet (approximately four miles from the runway) but it was not clear how the decision was usually made. One Australian airline defined a position in terms of radio altitude but as this information came from a report in the dataset, it had clearly not been an effective prompt to extend the landing gear in that case. What appears to distinguish the instances in the dataset is that the flight crew reach a point in the approach at which if the landing gear has not been extended, the prevailing contextual cues either fail to alert them to the fact or maybe even reinforce the belief that the landing gear is extended. Although it could not be determined this exact point, it was clear that if the landing gear remained retracted at 1000 feet it was unlikely that this was intentional. In summary, the situational context study was slightly more subjective than the other two contextual cueing studies but represent the best data available.

PART IV IMPLICATIONS OF THE ENTIRE RESEARCH

Chapter 10 outlines some of the human limitations and behaviours that have been examined and researched in this study. The chapter then critically examines this research's contribution to flight safety by citing its relevance to some of the safety occurrences in the literature. Finally, the chapter outlines how similar research could be deployed in other safety critical contexts.

CHAPTER 10

FINAL CONCLUSIONS, RESEARCH CONTRIBUTIONS AND IMPLICATIONS FOR AVIATION SAFETY

10.1 FINAL CONCLUSIONS

The primary aim of this research was to propose a new construct called substandard flight crew performance and to demonstrate how it could be used as a repository for knowledge relating to specific categories of safety occurrence. No existing reference source for the knowledge outlined in this research was found during the extensive literature review undertaken for this research. The fact that this thesis has applied the SFP construct to some accidents that had not even occurred at the time of its inception indicates that it has potential for both the investigation of current accidents and their mitigation. The LOC accident near Sumburgh (UK AAIB, 2016) occurred whilst this research was underway but as soon as the report was examined it was evident to this research that contextual cueing was probably a factor. This thesis has highlighted several instances where context appears to have adversely influenced the flight crew; such as the Buffalo accident flight crew's actions during the failed stall recovery (NTSB, 2010a, p. 90) and the actions of the Air Asia Airbus captain which led to a loss of control accident (KNKT, 2015). However, most of the research that enabled the operationalising of the aviation-related phenomena for all three research strands was from non-aviation sources. The process of accumulating knowledge from such a wide range of sources is one of the strengths of the SFP construct given that aviation' s stakeholders would not normally be drawn to those sources when seeking knowledge about aviation-related phenomena. By drawing these diverse knowledge sources together in one repository the SFP construct achieved its primary aim.

Detailed research into NPCs was long overdue given that they have featured in many of the most serious accidents in recent history. The Buffalo accident report (NTSB, 2010a, p.103) included a recommendation from the NTSB that the FAA develop, and distribute to all pilots, multimedia guidance materials including "a detailed review of accidents involving breakdowns in sterile cockpit and other procedures". The literature review undertaken during development of this research found no detailed examination of the underlying causes of NPCs. One of the aims of this research was to determine whether NPCs were researchable and if so, to conduct that research. The two taxonomies presented in this thesis confirm that the NPC is a researchable phenomenon and furthermore that there are behavioural and institutional underpinnings that appear to be unique to the aviation context. The objective of developing a taxonomy of flight deck conversation was effective inasmuch as the pilots who participated contributed their views and more is now known about the underpinnings of NPCs than was before. By developing a taxonomy of flight deck conversation types and their motives this research has achieved its aim of providing a repository for such knowledge that can be accessed by a range of aviation practitioners. Furthermore, by researching the possible causes of NPCs this research broke new ground and exceeded the FAA and NTSB's recommendation. In terms of the utility for aviation professionals of an increased knowledge of the underpinnings of flight deck conversation, there are a few possibilities. An example is found in this research's statistic that 25.6% of participants found narratives about a speaker's rapid progression within the organisation to be intimidating. It is unlikely that speakers like the NTSB vice-chairman or the captain of the Buffalo accident aircraft set out to make themselves unpopular by intimidating their colleague but the NPC research suggests that some pilots interpret that behaviour negatively. Given the orientation towards sociability and the links between group-cohesion and likeability outlined in chapter 7 of this thesis, it is conceivable that if it was clear that this behaviour is interpreted negatively by some co-workers, those who engage in it would be motivated to stop. Also if pilots knew that the strategic nature of flight deck conversation was transparent to their addressee they might be discouraged from engaging in it and the flight deck would revert to a less social but more business-like and safe place.

Although unclear communication is a recurrent feature of SFP-related occurrences, as far as is known, no previous research has referenced the general linguistics literature in the way this research did. Serious occurrences such as that at St Kitts (UK AAIB, 2010a) provide evidence that the strategic use of unclear language poses a threat to aviation safety so this research addressed a current and urgent aviation safety-related phenomenon. The St Kitts incident and other similar occurrences suggest that it is unsafe to assume that all those involved in aviation safety possess the insight or knowledge to make safe decisions regarding what to communicate and when to communicate it. The air traffic controller at St Kitts appears to have been strongly influenced by hierarchical structures and face–threat avoidance but it is unlikely a newly recruited air traffic controller, dispatcher or pilot would know where to begin to look for information on those subjects without conducting extensive research of a very wide range of literature, mostly unconnected to aviation. Narratives concerning factors such as hierarchy or face threat are rarely evident in aviation-related discourse but hierarchical influence and face threat avoidance were probably at the core of much of the unclear communication examined in this thesis. Some new concepts have been introduced, such as the idea that a sense of accountability/responsibility might lead to intentional miscommunication. It is very unlikely that this idea has been operationalised before but the explanations in this research provide plausible underpinnings for unexplained verbal behaviour evident in advance of an accident at Houston (NTSB, 1997a, p. 20) and other similar instances in the literature. In line with its stated aim, this thesis has identified some recurrent types of unclear communication by citing real-life instances. Almost all of the explanations offered for unclear communications outlined in this thesis were based upon peer-reviewed research and many are likely to be unfamiliar to pilots and support workers alike. Concepts that are probably new to aviation discourse such as “avoidance/avoidance conflict” and “locus of control” were introduced. From the foregoing it can be concluded that the unclear communication research outlined in this thesis achieved its research aim of explaining some of the reasons that unclear communication is such a recurrent feature of SFP-related safety occurrences. In terms of mitigating the effects of unclear communication, this research has outlined some very specific linguistic characteristics of unclear language that now they have been explained, should be more readily recognisable by flight crews thereby mitigating the risk of incidents like the near catastrophe at St Kitts occurring.

The aim of the spatial awareness research was to examine how flight crews’ cognitive load is affected when they face a spatial awareness task. The evidence for a proposed link between cognitive load and human error was outlined and the experiments demonstrated that cognitive load varied depending upon the type of task required. Although the experimental results were broadly as expected, the detail was less important than the general finding that spatial awareness tasks invoke cognitive load. The experiments provided a focus for the literature review-based explanations, all of which are relevant to the safe operation of aircraft in the contexts described. This thesis cited instances at Tenerife in the 1970s (UK AIB, 1981) and more recently at Cali (ACRC, 1996) and Jakarta (KNKT, 2012) where pilots have underestimated the influence of a spatial task and have failed to adjust their concurrent tasks accordingly. Notably, each of these flight crews mishandled the terrain escape manoeuvre they were attempting, so the link between spatial awareness tasks, cognitive load and SFP is empirically sound.

The aim of the contextual-cueing strand was to operationalise the concept of contextual cueing by placing it into an aviation context and to conduct research that reflected real life safety occurrences. To achieve the aim of operationalising contextual cueing in the aviation context, three hypotheses were developed and tested. Error rates were examined and it was found that certain identifiable contextual conditions did result in increased error rates. The notion of implicit learning (IL) was introduced and applied to a range of documented occurrences. The implicit nature of IL means that it is unlikely that the pilots affected would be aware of its influence, so the value of imparting this knowledge is its role in threat mitigation. If the captain involved in the previously cited runway collision at Tenerife had been aware of the possibility that his experience as a simulator instructor might expose him to increased risk of error he might have been more prepared for the cognitive error he made.

The situational-context research was operationalised using the example from occurrence reports of flight crews who forgot to extend their landing gear before landing. This was a difficult type of occurrence to research because the instances are few and pilots are very reluctant to own up to such a careless omission. It was evident from anecdotal and confidential accounts that could not be included in the research that similar errors and omissions are even more common than this study found. Despite this limitation, the research highlighted contextual conditions that have co-occurred with such occurrences. By providing theory-based explanations for phenomena such as failing to respond to flight deck noise or not noticing a warning light, this research achieved its aim of operationalising a range of realistic situational contexts that have preceded an aviation safety occurrence.

Development of the SFP construct was inspired by the reports into two seminal accidents, one at Lexington (NTSB, 2007a) and one at Buffalo (NTSB, 2010a), which acknowledged the shortcomings of the flight crew but admitted that the underlying reasons for those shortcomings were unclear. It was evident from the reports that verbal communication, loss of situational and positional awareness and contextual influences were highly instrumental in both these accidents. This research commenced from the premise that the flight crews' performance was substandard and examined some of the influences that may have contributed to that performance. For instance, Hersman (2010, p. 6) highlighted a persistent narrative related to employment terms and conditions that young and inexperienced pilots encounter early in their careers; as far as is known, no previous research has suggested that this might provide a context for the kind of rule infringement evident in the Buffalo report. So although the first part of the verbal strand was about NPCs it was also, to some extent, a treatise on the role of the institutional features of the aviation system that contribute to SFP. The section on aviation's stakeholders highlighted that even those on the periphery of aviation can be implicated in an accident; the longest conversation in the transcripts related to an administrator who was perceived by the FCM speaking to have been treating her unfairly. Abstract topics such as this do not receive much attention in aviation related research but the conversation section of this research did not shrink from this topic. The verbal strand also attempted to explain why previously inexplicable communication failures like the one that almost caused a catastrophe at St Kitts occurred. The influence of hierarchy was examined in more depth than could be located in previous research. This is important because, in common with the St Kitts occurrence, a recent CFIT accident at Birmingham, Alabama featured behaviour that may have been underpinned by hierarchical structures that exist in the aviation system. The verbal strand included controversial research into flight deck conversation that some pilots might find uncomfortable to read but the taxonomies developed for this research were validated by pilots and explain narratives very similar to those heard from the flight crews at Lexington (NTSB, 2007a), Buffalo (NTSB, 2010a) and in other reports. It is not being suggested that most pilots behave in this fashion, but some clearly do, so it is important to understand why. NPCs are a persistent factor in aviation accidents so the relevance of this research is clear.

Unclear communications have been examined in a range of institutional contexts but this was among the most complete examinations of the potential underpinnings of failed communication in aviation operations. The linguistic literature reviewed for this section of the study was characterised by an absence of <u>hard science</u> so inevitably in this section <u>soft science</u> and subjectivity predominated. The research aim of identifying and explaining some of the most recurrent instances of unclear communication was achieved insofar as theory-based explanations were proposed for several real life occurrences. It should be noted that the research aim was not to identify *all* such unclear communication so if this research attracts critique and alternative assessments, the overall aim of the SFP construct, to provide a repository for such knowledge, will also have been advanced.

Whilst the spatial awareness strand may have appeared to be about why pilots get lost despite having excellent map displays, it was in fact about identifying, validating and explaining one of the reasons why their cognitive load gets out of control. The research aim was to examine how flight crew cognitive load is affected when it is necessary to reorient from an observer-centred ND to a chart of a different reference frame. Although reorientation was found to influence cognitive load, at the conclusion of this research it was not possible to clearly identify the type of spatial task that pilots find most cognitively challenging. However, the insights gained provided a springboard to discuss some of the factors that might cause these peaks in cognitive load. By providing a repository for the type of knowledge outlined in the spatial awareness strand the SFP construct has potential to cause those who support flight crews to reflect upon the effect that their actions have upon the cognitive load of the flight crew. The air traffic controller at Tenerife (UK AIB, 1981) who instructed a Boeing 727 flight crew to enter a holding pattern with almost no time to prepare was one of several examples of a failure to empathise. When searching for an explanation for this type of behaviour, the closest existing construct is emotional intelligence (EI); however, this is not a perfect fit for the phenomena identified in this research. In informal discussions with pilots there was a tendency to dismiss the EI construct just because of its name, which would be disappointing because this research indicated there is a requirement to develop a similar construct that more accurately reflects the type of behaviour experienced at Tenerife. This would enable the necessary skills to be taught and more importantly, to be checked in just the same way as technical skills are checked.

Although the contextual cueing strand examined an original construct, there was evidence for its existence in the reports. This research is thought to be the first to attempt to operationalise the construct and conduct experimental research. This research confirmed that three categories of implicit knowledge influence flight crews to make errors; these were knowledge gained from their situational context, the status of their systems, and the typicality of an alert or indication. By conducting experiments and literature-review based analysis this research achieved the research aim of operationalising contextual cueing in an aviation setting.

This preliminary study of contextual cueing has implications that spread way beyond the aviation context. An example of system-status contextual cueing was evident in a 1988 fatal rail accident at Le Gare de Lyon in Paris (world heritage.org). The train's driver and guard disabled the train's brakes after making an incorrect assumption relating to the system status after a passenger had deployed the emergency braking system.

The alert/indication contextual cueing experiment confirmed that there is a significant preference for the most typical response to an alert even if this is the wrong response. This has implications for aircraft design; manufacturers should ensure that their aircraft do not have ambiguous warning systems. The report into a depressurisation accident near Athens (AAIASB, 2006, p. 110) provided several examples of flight crews confusing the cabin altitude warning for a takeoff configuration warning that was only possible on the ground.

10.2 CONTRIBUTION TO AVIATION SAFETY

1. Development of a taxonomy of flight deck conversation.

In addition to developing and validating two original taxonomies of flight deck conversation, this research introduced several well-documented concepts from more general research to the aviation context, such as locus of control, work-motivation theory, powerlessness and powerfulness, organisational citizenship and others. Furthermore they were each proposed as an explanation for a real life extract of verbal interaction from the reports. An example of this contribution is found in the detailed explanation in sections 7.1.12 and 7.1.17 of the verbal behaviour of the first officer in the Buffalo (NTSB, 2010a) accident, one of the most serious SFP-related occurrences in recent history. No detailed explanation for this behaviour could be located in the existing literature.

2. A detailed examination of unclear communication and its function in the aviation context.

In much the same way, the unclear communications research identified recurrent instances of unclear communication and sought explanations from the wider literature. The research orientation was towards linguistic hedging; no existing research relating to concepts such as hedging could be located in the aviation related literature. The underpinnings of hedged communications as outlined by Bavelas (1985) provided a plausible explanation for the reluctance to speak up when things are going wrong. No previous research could be found that has attempted to demonstrate and explain the language used when, for instance a rule is about to be infringed (See section 7.2.6.1) or a mistake has been made (See section 7.2.6.3), despite there being a recurrent pattern to the language used in such instances. Serious runway incidents at St Kitts and Manchester outlined in section 7.2.4 demonstrate that whilst attenuated language can often be identified in hindsight, it frequently fails in its communicative objective at the point of use. As far as is known, aspects of general linguistics such as Grice's (1975) co-operative principle of conversation have never been considered in an aviation context before but if the speakers in the incidents above had applied Grice's maxims (outlined in section 7.2.4.) it is unlikely that the misunderstandings that resulted in the incident would have occurred. By accessing the very considerable linguistics-related literature, this research has broadened the study of aviation communications from a largely technical discipline to one concerned with getting the message across and securing aviation safety.

3. A detailed explanation of the relationship between spatial awareness tasks, cognitive load and human performance supported by experimental evidence.

There is a long history of pilots losing control and crashing whilst dealing with a spatial awareness challenge. These are highly avoidable accidents which can develop from a completely routine flight to a crash in two or three minutes. Although the link between cognitive load and human performance is intuitive, it was not possible to locate any aviation research linking cognitive load to working-memory capacity despite quite an extensive literature on the subject (e.g. Hinson et al., 2002, 2003). There is also very little aviation-related research into mental reorientation and spatial ability so this research adds to a very sparse knowledge bank. This research has challenged the notion that providing a moving map necessarily improves spatial awareness (Prinzel et al., 2005). A particularly important contribution to the field is the distinction between wayfinding and navigation, which is original to this research. During the literature review conducted for this research no literature was found which described the cognitive processes that have resulted in loss of spatial-awareness accidents so the contribution of this research is clear.

4. The introduction of contextual cueing as an aviation related human factor supported by experimental evidence

The operationalising of contextual cueing in the aviation context was long overdue given that it had been described in accident reports dating back to 1970s (Ministerio de Transportes y Communicaciones Subsecretaria de Aviacion Civil, 1978) and as recently as 2016 (UK AAIB, 2016) but is virtually unresearched as an aviation related human factor. This meant that until the research outlined in this thesis there was no repository for knowledge relating to the construct. By operationalising contextual cueing on the basis of experimental evidence this strand of the research outlined how the SFP construct could be used in the future when it is suspected that a flight crew may have been influenced by contextual cues.

<u>5. The introduction and validation of a more effective method of categorising specific types of human limitations and behaviour than currently exists</u>

The overall contribution of this research was to define what substandard flight crew performance is and to illustrate how SFP research is conducted. Aviation safety is a dynamic subject and the types of accidents that occur seem to go in cycles. As this is written there is an increase in pilots who lose awareness of the status of their autopilot and this has resulted in one recent fatal accident and two near catastrophes[xvi]. Some of the human limitations involved in this type of occurrence have by coincidence been outlined in this thesis. Mishandling of the autopilot could readily be a subcategory of system-status contextual cueing thereby providing access to a very substantial amount of data relating to these accidents. These data could be used for accident analysis or more optimistically, to help prevent such occurrences in the first place.

10.3 WIDER IMPLICATIONS FOR HIGH RELIABILITY ORGANISATIONS

Outside aviation, accidents at Three Mile Island and Ladbroke Grove were instances of alert/indication contextual cueing. At a nuclear plant at Three Mile Island the operators had become so accustomed to a particular warning light providing accurate system status that when it started to provide indications that did not match their expectations they dismissed the conflicting information and a serious nuclear accident resulted. Detailed research by Stanton & Walker (2011) into the rail collision at Ladbroke Grove noted that the inexperienced driver had always previously experienced a green proceed signal at the gantry which he passed at red on the day of the accident. Stanton & Walker (2011) speculated that the driver may have started forming his belief about the upcoming signal before sighting it. A recent rail accident at Santiago in Spain occurred in a context in which a malfunctioning warning system had been disabled due to false alerts, so this was the converse case, in which it is conceivable that the driver would have become habituated to an alert that would now be absent.

This thesis also outlined how flight crews sometimes forget to extend the landing gear because their situational context, or where they are in space, predicts that it should already be extended. The situational context hypothesis can also be applied to rail accidents. One hypothesis offered in the case of a tube train accident at Moorgate in 1975 was that the driver simply got two stations with several common contextual features, mixed up and didn't notice that he was entering a terminus. Two drivers interviewed by the BBC (2010) commented that they had become confused between stations on this line due to the similarity of some of the features of the stations. The report into a 2004 derailment at Berajondo, Queensland, Australia (ATSB, 2005) involving a tilt train which took a bend at too high a speed commented that there was "a real possibility that the driver suffered an initial lapse of concentration and thought that he was on the section of track…some 5 km further on, where a similar left hand curve is 110 km/h for the tilt train and 90 km/h for freight trains". Notably, the report (Ministerio de Fomento, 2013) into a very similar derailment accident at Santiago, Spain in 2013 did not even consider the possibility that the driver might have been influenced by contextual features of his spatial environment, preferring to attribute the accident solely to driver error. Although Section 4.4 on stakeholders proposed some reasons why an operator might choose to adopt such a position, it is also possible that contextual cueing was simply not understood by investigators, so the contextual-cueing hypotheses can be seen to contribute to safety at many levels.

Although the former two examples involved speculation, the previously cited rail accident at Ladbroke Grove in 1999 bore some irrefutable features of situational contextual cueing. On the day of the accident, the inexperienced driver experienced a signalling arrangement that he had never before experienced before in his total of nineteen journeys from Paddington (Stanton and Walker, 2011, p. 1122) so his situational context would likely cue him to pass the signal he ignored on the accident journey. Learned Counsel pointed out that in the prevailing contextual conditions the driver could have been under the impression that the red signal he passed was not there or did not apply to his line (Cullen, 2001, p. 73). In the marine context, the highly publicised sinking of the Costa Concordia cruise liner near the island of Giglio also featured a repetitive situational context. The errant ship's master was repeating a manoeuvre that he had successfully completed several times before; however, according to the report (MIT, 2012) he may have formed a "false hypothesis" (Ibid., p. 162) based upon his previous experience. Unfortunately on the day of the accident his situational context was different in two crucial respects. He had used a different turning point and was using a higher speed, so whilst his previous success probably gave him confidence to complete the planned manoeuvre, he was in a slightly altered situational context. The Costa Concordia accident represents an example of the interconnectedness of the three research strands chosen for this research. In addition to the contextual factors outlined above, the report commented on the "overall passive attitude of the bridge staff; nobody seemed to have urged the master to accelerate the turn or to give warning of the looming danger" (Ibid., p. 6). This unwillingness of subordinates to speak up clearly permeates marine safety just as with aviation. The master of the Costa Concordia waited a very long time before he admitted to emergency services that his actions had resulted in the grounding of his craft, having previously referred only to having an electrical black out. The report comments that he described "a scenario less serious than reality" to the crisis centre and even told them the situation was under control despite the ship being mortally damaged. This tendency to understatement during a crisis of one's own making is reminiscent of the actions of the first officers at Detroit (NTSB, 1991b) and Houston (1997a) and the captain at Charleston (NTSB, 2010c).

These and many other examples indicate that the SFP construct and the types of research outlined in this thesis have the potential to be adapted to a range of safety-critical contexts. As a pilot, the researcher found that although marine and rail accident reports were similar in layout to aviation reports, the vocabulary was as bewildering to him as the aviation vocabulary would be to experts in those other disciplines. However, this research was able to incorporate knowledge from rail and marine safety quite readily in this research so it is likely that the principles outlined in this thesis would be comprehensible enough to be applied to a wide range of safety-critical disciplines. The stakeholders who are involved in rail or marine accidents are just the same as the stakeholders in aviation outlined in Section 4.4 of this thesis and the knowledge outlined in this thesis is relevant to them all.

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APPENDICES

APPENDIX A

THE OCCURRENCES CITED IN THIS THESIS IN ALPHABETIC ORDER OF LOCATION.

Amsterdam	Boeing 737: Loss of control and collision with terrain on final approach. Aircraft stalled due to substandard monitoring of speed.
ARKANSAS	Convair 600: Controlled flight into terrain whilst avoiding weather. (1973)
ASPEN, COLORADO	Gulfstream business jet: Controlled flight into terrain whilst approaching a mountainous airport. Flight crew knowingly flew below the minimum altitude for the approach. (2001)
Athens	Boeing 737: Loss of control after flight crew incapacitation. The flight crew misconfigured the cabin pressurisation resulting in loss of consciousness. (2005)
Atlanta	Boeing 767-300: Taxiway landing at night after late runway change. (2009)
Auckland	Boeing 747-412: Tail Strike during takeoff due to incorrect speeds set and flown. (2003)

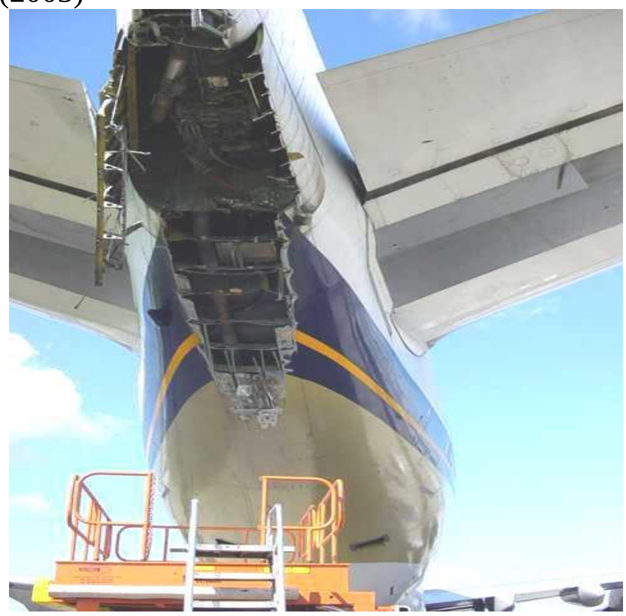

Photo courtesy of International Air Safety Association

Barcelona

Bombardier CRJ: landing gear remained retracted for landing whilst performing a planned flapless landing. (2007)

Photo courtesy of CIAIC.

Basle

Airbus A320: Controlled flight into terrain during a low flypast at an air show. (1988)

Bedford, Massachusetts

Gulfstream business jet: Runway overrun during rejected takeoff due to attempting to depart with the control locks engaged. (2014)

BEIRUT

B737: Loss of control after takeoff due to loss of aircraft state awareness. (2010)

Berajondo, Queensland

Derailment of a tilt train whilst entering a bend at high speed.(2004)

Birmingham, Alabama

Airbus A 300: Crash during a night time non-precision instrument approach. Rushed approach after a late runway change. (2013).

Bristol

Airbus A319: Disorientation during a night visual approach. (2015)

Buffalo

Bombardier, DHC 8-Q400: Loss of control on approach due to distraction. Captain had a history of substandard performance; first officer was relatively inexperienced. (2009)

CALI

Boeing 757: Controlled flight into terrain and Loss of control after loss of position awareness following a runway change. (1995)

CAMEROON

Boeing 737-800: Loss of control after takeoff. (2007)

CHARLESTON	Bombardier CL600: Runway overrun after late rejected takeoff. Captain attempted to select the flaps during the takeoff run after noticing they were incorrectly set. (2010)

Photo courtesy of Charleston Airport.

Charlotte	Douglas DC 9: Controlled flight into terrain due to distraction caused by conversation. (1974)
CHICAGO	Boeing 737: Runway overrun and collision. Mishandling of braking and reverse thrust during landing on a snow covered runway. (2005)
Comoros	Airbus A 310: Controlled flight into terrain and loss of control during a circling approach. (2009)
Dallas	Boeing 727-232: Flapless takeoff and loss of control.(1988)
Denver	McDonnell Douglas DC 9-14: Loss of control. Inexperienced captain and first officer. Mishandling by first officer and procedural omissions by captain. (1987)
DETROIT	Douglas DC 9/Boeing 727: Runway incursion and collision. The DC9 flight crew became disoriented during taxi out. The captain was out of practice and the first officer exaggerated his knowledge. (1990)

Photo NTSB©

Dryden	Fokker F 28: Loss of control due to airframe icing (1989)
Dubrovnik	Boeing CT 43: Controlled flight into terrain. VIP military flight crew at an unfamiliar airport. (1996)
DULLES	Boeing 727: Controlled flight into terrain after expressions of uncertainty relating to the lowest safe altitude. The aircraft was diverting from its intended destination. (1974)
Gatwick	Boeing 767: Approach to low altitude with landing gear retracted. Air traffic control at Gatwick requested a high speed on final approach and the flight crew omitted to extend the landing gear until they received a warning. (2005)
Guam	Boeing 747: Controlled flight into terrain. Flight crew appeared to be unsure of the status of the electronic glideslope and flew into the ground. (1997)
GUANTANAMO BAY	Douglas DC 8: Loss of control during a difficult approach. There was no need to fly the difficult approach. The aircraft crashed in an extreme attitude just short of the runway. (1993)
Heathrow	Boeing 777: Stalled onto runway after both engines failed. This dual engine failure was probably the result of fuel icing. The flight crew did well to make the runway. (2009)
HOUSTON HOBBY	Gulfstream: Crash during approach to landing. The PM made a mistake setting the navigation displays which distracted the PF. The aircraft crashed several miles short of the runway. (2004)

Houston	Douglas DC 9: Wheels up landing. New captain misinterpreted several warnings which resulted from a system configuration error. He continued the approach despite the warnings and landed with the gear retracted. (1996)

Photo B Correira ©

Irish Sea	Boeing 737: Mishandled cabin pressurisation. The flight crew omitted to pressurise the aircraft cabin and failed to respond to indications that should have alerted them to that fact. (2011)
ISLAMABAD	Airbus A 321: Controlled flight into terrain and loss of control. Captain attempted to fly an unauthorised approach in bad weather. He became overloaded and made multiple errors. (2010)
JAKARTA	Sukhoi RRJ95B: Controlled flight into terrain. The captain was a test pilot demonstrating a new airliner to customers. He flew the aircraft into a mountain when he became distracted. (2012)
Java Sea	Airbus A320: Loss of control after inflight troubleshooting. (2014)
Johannesburg	Boeing 747: Taxied into a building. Aircraft scrapped (2013)
Kaliningrad	Boeing 737: Landing gear retracted landing after problems with the flaps. (2008)
Kansai	Boeing 777 300: Approach to a closed runway whilst flying a night time visual approach which neither pilot had flown before. (2011)
Kegworth	Boeing 737: Shut down the wrong engine after a fire warning.(1989)

Ketchican	De Havilland DHC 3: Controlled flight into terrain during a sightseeing flight. (2015)
Kirksville, Missouri	BAE Jetstream: Controlled flight into terrain during a night time non-precision approach. (2004)
La Guardia	McDonnell Douglas MD 88: Descent below visual glidepath and collision with terrain. (1996)
Ladbroke Grove	The Ladbroke Grove rail enquiry: Collision between two trains. (2000)
Lanzarote	McDonnell Douglas MD 83: Flapless takeoff and loss of control. The aircraft had existing defects which may have influenced the flight crew. Landed safely.(2007)
LEXINGTON	Bombardier CL 600: Attempted takeoff from wrong runway at night. The runway the flight crew used was about half the required length and misaligned by 40˚. The aircraft hit trees and an earth mound. (2006)
Lulea	Boeing 737: Wrong runway takeoff in fog. This flight crew took off on the reciprocal runway to that intended; only noticed after takeoff. (2007)
Madrid	DC9 82: Flapless takeoff and loss of control. Taxiing out for the second time after experiencing a defect earlier, the flight crew omitted to extend the flaps for takeoff. The aircraft stalled just after takeoff. (2008)
Manchester	Boeing 737: Took off with crew unaware that runway was reduced in effective length. Misunderstanding related to the entry point on the runway. (2003)
Melbourne	Boeing 737: Incorrect go around procedure after windshear event. (2010)
Miami	Boeing 777: Took off from wrong runway intersection and hit lighting gantry. (2015)
Milan	Boeing MD 87/Cessna 525: Runway collision in fog. The Cessna pilot became lost on the airport and taxied into the path of the MD 87. (2001)
Moorgate	London Underground train crashed into buffers at high speed.(1975)
MOUNT EREBUS	Douglas DC 10: Controlled flight into terrain. Sightseeing flight in marginal weather. Incorrect navigation coordinates provided to flight crew. Multiple expressions of concern from FCMs preceded flight into the mountain. (1979)

MOUNT TEIDE, TENERIFE	Boeing 727: Controlled flight into terrain. Late change to clearance requiring flight crew to enter an unpublished holding pattern. This combined with the aircraft being flown faster than normal resulted in the flight crew becoming hopelessly lost and flying into the mountain. (1980)
Nassenwil Austria	Saab 340B: Loss of control after takeoff. Captain became confused after turning the wrong way on departure. (2000)
Newcastle U.K.	Boeing 757: Loss of control after go-around. Procedural errors resulted in a loss of control and a low fuel emergency landing. The aircraft was completely serviceable. (2013)
New York JFK	Boeing 707, Ran out of fuel. Flight crew did not manage fuel state during poor weather conditions. (1990)
Palmerston North, New Zealand	De Havilland Dash Eight: Controlled flight into terrain. Captain became distracted whilst a problem with the landing gear was being addressed. (1995)
Paris	Shorts SD 330/ McDonnell Douglas MD 83: Runway collision. The Shorts entered the runway in front of the departing MD 83 after misinterpreting a clearance. This was a line training flight with a new co-pilot.(2000)
Pekanbaru, Indonesia	Boeing 737: Failed flapless takeoff and runway overrun. (2002)

Photo NTSC ©

PORTLAND	McDonnell Douglas, DC 8 61: Fuel Exhaustion whilst troubleshooting

	a landing gear problem.(1978)
Providence	Boeing 757/ Boeing 727: Near runway collision in fog. The air traffic controller lost situational awareness after the 757 flight crew reported being lost in the vicinity of the active runway. (1999)
River Hudson	Airbus A320: Loss of thrust in both engines due to multiple bird strikes resulting in ditching. (2009)
Romulus	Douglas DC 9: Flapless takeoff and loss of control. Flight crew omitted to extend flaps for takeoff.(1987)
Roselawn, Indiana	ATR 72: Loss of control after icing encounter. Flight crew distracted and failed to notice low speed whilst holding. (1994)
San Francisco	Boeing 777: Descent below visual glidepath and impact with seawall. Captain under training mishandled the thrust on approach and the training captain and third pilot did not notice. (2013)
Santiago	Crash of high speed train which entered a bend at too high a speed. The driver was distracted by his mobile phone in the period preceding the crash. (2013)
Sharjah	Ilyushin Il 76: Approached an under construction Runway. Multiple expressions of uncertainty during the approach. (2014)
SHARM EL SHEIKH	Boeing 737: Loss of control after takeoff. Reason unclear.(2004)
Smolensk	Tupolev TU-154: Controlled flight into terrain. Military VIP flight with pressure to land from superiors. (2010)
SOCHI	Airbus A320: Loss of control and collision with the surface. Confusing missed approach instruction and substandard operation by flight crew. (2006)
ST KITTS	Boeing 777-236: Takeoff from wrong position on runway. No taxi briefing by flight crew because this was considered a simple airport. Flight crew took the wrong intersection for takeoff and despite being aware of this error the air traffic controller did not alert them. Nearly ran out of runway. (2009)
St Louis	McDonnell Douglas DC 9-82: In flight left engine fire. Multiple procedural infringements made a difficult situation even worse. (2007)
Staines, UK	Hawker Siddeley Trident 1: Loss of control after takeoff. Two inexpe-

	rienced co-pilots and a senior captain. Aircraft stalled after flaps were retracted at too low a speed. (1972)
Sydney	Bombardier DHC 8-315, Stall warning device event. Training flight; rushed approach resulting in failure to monitor system configuration. (2011)
Taiwan	Boeing 747: Crashed into equipment on partially closed runway during takeoff. Flight crew lined up on a closed runway despite disconfirming indications inside and outside the flight deck. Crashed into heavy equipment at high speed.(2000)
TENERIFE NORTH	Boeing 747/Boeing 747: Collided on the runway during fog. A Dutch flight crew commenced takeoff on an occupied runway after the captain misinterpreted a clearance. (1977)
Three Mile Island	Nuclear meltdown accident after incorrect assessment of system status. (1979)
WASHINGTON	Boeing 737-222: Stalled after takeoff due to incorrect thrust setting resulting from erroneous engine indications due to ice accretion. (1982)
ZURICH	Avro 146-RJ 100: Controlled flight into terrain after an unexpected runway change. The flight crew knowingly flew below the altitude minima for the approach. (2001)

APPENDIX B: THE ONLINE CONVERSATION QUESTIONNAIRE

Loughborough University

Flight deck Conversation Survey
Explaining flight deck conversation: The pilot's perspective

Thank you for agreeing to participate in this survey. This questionnaire is part of a human factors research programme including a study of the types of conversations that occur on the flight deck. Existing research into conversations in institutional settings suggests that such conversations are often carefully constructed, and deployed with a particular objective in mind.
You are being asked to identify what you consider your colleague was trying to achieve by conducting certain types of conversation that you may have experienced on the flight deck. It is unimportant whether the conversation in question occurred during a sterile cockpit period or not.

The **Explanation List** below is derived from existing organisational and social science research, adapted to reflect the airline context. Both the conversation types and the explanation list have been subjected to extensive critique by pilots from several airlines in order to make them recognisable to you. Any alternative explanations you offer are also very important to this research, so please provide your personal insights.

EXPLANATION LIST
The following list describes some possible explanations for the conversation types you will be assessing. Hit the 'More Info' button to get a pop up window with these explanations when you are filling in the survey.
SELF-PROMOTION

Where individuals point out or allude to their abilities or accomplishments in order to be seen as competent, successful and autonomous (self-governing).
INGRATIATION

Where individuals use flattery or excessive self-deprecation to appear likeable to colleagues
EXEMPLIFICATION

Where individuals describe self-sacrificing or going above and beyond the call of duty in order to appear dedicated to their work
CREW COHESION
Where conversation is enacted to reinforce the impression that the speaker belongs to a like-minded group to the listener
SELF-JUSTIFICATION

Where conversation is enacted to explain and justify some aspect of the speaker's situation or actions; this can involve selective omission or inclusion of relevant information
INTIMIDATION

Where conversation tends to overawe, unsettle or invoke a sense of inferiority or inadequacy in you, either personally or professionally

NORMAL FRIENDLINESS
Where conversation is enacted in the interests of normal social interaction, characterised by co-operation and agreeableness; speakers are neither excessively introverted nor extraverted in such interactions

ANY OTHER EXPLANATION

Below is an extract from the flight deck conversation questionnaire illustrating one of the 28 conversation type categories.

3. Flight deck Conversation types

For each conversation type listed below choose your first and second choice explanation from the dropdown list.

If you do not recognise the conversation type, leave the box blank. If you do not have a second choice explanation, leave that box blank, although few conversations are likely to have a single explanation.

If none of the explanations offered in the dropdown list is appropriate, please offer your alternative explanation(s) in plain language in the "other" boxes. These alternative explanations are a very important component of this research.

	Choose your primary explanation for this behaviour.		**Choose your secondary explanation for this behaviour.**	
	(please select)	**Other *(please specify)***	***(please select)***	**Other *(please specify)***
Mentioning an occasion when a favour was done for a colleague or the organisation	Other...		Select an answer	

APPENDIX C: CAVEAT REGARDING USE OF ASRS DATA

Certain caveats apply to the use of ASRS data. All ASRS reports are voluntarily submitted, and thus cannot be considered a measured random sample of the full population of like events. For example, we receive several thousand altitude deviation reports each year. This number may comprise over half of all the altitude deviations that occur, or it may be just a small fraction of total occurrences.

Moreover, not all pilots, controllers, mechanics, flight attendants, dispatchers or other participants in the aviation system are equally aware of the ASRS or may be equally willing to report. Thus, the data can reflect reporting biases. These biases, which are not fully known or measurable, may influence ASRS information. A safety problem such as near mid air collisions (NMACs) may appear to be more highly concentrated in area “A” than area “B” simply because the airmen who operate in area “A” are more aware of the ASRS program and more inclined to report should an NMAC occur. Any type of subjective, voluntary reporting will have these limitations related to quantitative statistical analysis.

One thing that can be known from ASRS data is that the number of reports received concerning specific event types represents the lower measure of the true number of such events that are occurring. For example, if ASRS receives 881 reports of track deviations in 2010 (this number is purely hypothetical), then it can be known with some certainty that *at least* 881 such events have occurred in 2010. With these statistical limitations in mind, we believe that the real power of ASRS data is the qualitative information contained in report narratives. The pilots, controllers, and others who report tell us about aviation safety incidents and situations in detail – explaining what happened, and more importantly, why it happened. Using report narratives effectively requires an extra measure of study, but the knowledge derived is well worth the added effort.

APPENDIX D: AN EXTRACT OF COMMUNICATIONS DEMONSTRATING LOSS OF SPATIAL AWARENESS

This is an extract of communications between a Korean flight crew proceeding downwind on a circling approach and Busan ATC. APP is the approach controller and ABL8108 is communication from the flight crew. At time 14:19:54 the first officer is clearly confused between left and right. Also note how the reply at 14:20:06 omits the word right and the acknowledgment of clearance to land at 14:22:26 doesn't mention the runway at all. The aircraft was landed on a runway parallel to that intended.

14:13:32	APP	ABL8108 turn left heading 330, descend to 4,000, cleared for localizer 36 left, circle to runway 18 right, report established.
14:13:38	ABL8108	Heading 330, 3,000, cleared ILS, cleared localizer DME 36 left circle to land runway 18 right, report established, ABL8108.
14:19:05	ABL8108	Gimhae approach ABL8108, runway in sight.
14:19:08	APP	Roger, 8108 circle west of the airport for right downwind, contact tower 118.1, good day.
14:19:54	ABL8108	Gimhae tower ABL8108, runway oh, circle runway 18 lef right, runway in sight.
14:20:02	TWR	ABL8108 circle to runway 18 right, report right downwind.
14:20:06	ABL8108	Report downwind, ABL8108.
14:22:11	TWR	ABL8108 not in sight, check wheels down, wind 190 at 14, cleared to land runway 18 right.
14:22:17	ABL8108	Gimhae tower ABL8108, turning base.
14:22:21	TWR	8108, not in sight, I say again, cleared to land runway 18 right.?
14:22:26	ABL8108	Cleared to land(기장? 배경음), cleared to land ABL8108.

APPENDIX E
EXTRACT OF NASA ASRS REPORT 438691, MAY 1999

A Boeing 747 flight crew realized an incorrect flap setting after the before takeoff checklist was run on taxi out of JFK.
Narrative: Crew of 3 (captain, first officer, flight engineer) on a cargo flight from JFK to Atlanta and then on to Anchorage. Initial departure had been delayed about 2 hours due to the late arrival of aircraft to JFK. After engine starts and taxi clearance received, captain called for 'flaps 10 degrees. First officer moved the flap handle and called “flaps 10 degrees”. While taxiing to hold short, taxi checklist was accomplished. At the checklist step for “flaps and runway” (for which the captain has no response), I happened to glance at the airport diagram to check on a taxi routing instruction which we had just received. At “flaps and runway” on the checklist, the first officer called out “10, 10, green light” (indicating that the inboard and outboard flap indicators actually show flaps at 10 degrees and the flap position light is green). The flight engineer then called out “10, 10, 8 green lights”, which acknowledged his confirmation of flap position. Through it all, the flaps were at 5 degrees.

APPENDIX F

ILLUSTRATIONS OF SOME OF THE EQUIPMENT REFERRED TO IN THIS THESIS

This illustration shows the instrument layout on a Boeing 787. The ND is on the extreme left and is aligned with an egocentric heading of 047°or northeast at the top of the instrument. The EFB is on the right and is fitted at an angle to the viewer. The EFB image is oriented with north at the top and the aircraft's position and orientation on the apron can be seen in amber on the map. Below is an enlarged image of the same EFB with its allocentric orientation.

An EFB showing the aircraft parked on the gate heading north east.

The image below shows a modern flight management computer (FMC) on the left and an ACARS display on the right.

ENDNOTES

[i] The term substandard in relation to flight crew performance is used in NTSB reports AAR 94/05, 88/05, 93/03 and 89/04.

[ii] A Boeing 737 took off in fog at Lulea, Sweden using the reciprocal runway to the one intended. This suggests that the flight crew were completely disoriented when they commenced their takeoff. An identical type of aircraft to the Buffalo (NTSB, 2010a) accident aircraft was involved in a very similar occurrence at Sydney in 2011. The report into an Airbus crash at Birmingham Alabama in 2011 commented that the flight crew's conversation regarding non-pertinent operational issues distracted them.

[iii] The fatal accident involved a Piper PA 46 and the two serious incidents involved a Boeing 757 and a Saab 2000.

[iv] The report into an accident at Roselawn omitted some CVR transcript data and the Russian report into the Airbus crash at Sochi failed to acknowledge human factors in relation to communication that the French BEA considered pertinent to the cause.

[v] The SACAA report (2014, p. 93) into a Boeing 747 taxiing accident cited a similar previous BA 747 incident that had not been reported.

[vi] FAA to boost pilot professional development (FAA, 2016)
Following the Colgan Air Flight 3407 accident, air carriers and unions responded to the FAA's Call to Action and pledged support for professional standards and ethics committees, a code of ethics, and safety risk management meetings.

[vii] Both the Buffalo and Kirksville reports include positive testimony related to the captains conducting a relaxed operation.

[viii] Remarks of Robert Sumwalt, Vice Chairman National Transportation Safety Board to SMU Air Law Symposium February 21, 2008 Dallas, TX

[ix] The Buffalo first officer spoke of going to Alaska Airlines. The Buffalo captain had turned down a jet job. The Lexington first officer spoke of going to Southwest and to a Middle East carrier. The Detroit first officer had three job offers and this was not his first choice.

[x] Maurice Nevile (2006) researched the reasons that pilot preface some of their talk with the word "and". Although this is a legitimate linguistic study it has little practical value to aviation operations.

[xi] Astronaut Alan Shepard used the term when commenting on a rocket explosion he witnessed in 1959. Shuttle astronaut Robert Gibson also used it in relation to a cabin leak warning.

[xii] See ASRS reports 1042772,1307627 and 1277512

[xiii] The NTSB accident database details accidents at Detroit, Charleston and Dallas in which pilots responded to a checklist item without checking the item.

[xiv] An Ethiopian crew departing from Beirut misinterpreted multiple heading instructions prior to losing control of the Boeing 737. An Armenian Airbus crew failed to fly the correct heading on a missed approach and crashed into the sea shortly after. A Boeing 757 crew crashed into a mountain near Cali just four minutes after an incorrect modification to the route caused navigation confusion.

[xv] Since 2014 there have been gear retracted landings involving training flights in Taiwan (ASC, 2015), Canada (Transport Canada, 2016) and Spain (CIAIC, 2016).