Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.
Flights into Deteriorating Weather Conditions: Investigating Cognitive Biases in Weather-Related Decision Making

A thesis presented in partial fulfillment of the requirements for the degree of:

Doctorate of Philosophy

In

Aviation

At Massey University, Manawatu

New Zealand

Stephen Walmsley

2016
Abstract

In this thesis, the author’s aim was to investigate whether the use of three cognitive heuristics may lead to systematic biases leading visual flight rules (VFR) qualified pilots to make inappropriate or ineffective decisions when faced with adverse weather and fly into instrument meteorological conditions (IMC). Although heuristics may reduce cognitive workload in weather-related decision making, they may lead VFR pilots to judge weather conditions as being better than they are in reality and continue flight into IMC conditions, when diverting or turning back would be the judicious choice.

Three cognitive biases that may potentially occur in pilot decisions to fly from VFR into IMC were identified: anchoring effect, confirmation bias and outcome bias. Three vignette-based studies found that pilots tended to anchor and under-adjust on initial information ($n = 201$), favour a confirmatory strategy when testing a hypothesis ($n = 278$) and evaluate judgments by the outcome rather than the decision process ($n = 300$).

Three intervention studies tested whether encouraging pilots to consider additional information rather than focusing on a narrow set of evidence when making judgments could reduce the impact of the three cognitive biases. Although a ‘consider the alternative’ strategy is sometimes effective, it was largely unsuccessful in reducing all three cognitive biases ($n = 101$). The perseverance of the biases in all six empirical studies is discussed in relation to the extant literature, as are the implications for flight-training and general aviation pilots generally.
Acknowledgments

I would like to express my appreciation to a number of people for their support and advice over the several years on my PhD journey.

I would like to express my sincere appreciation to my supervisor, Dr Andrew Gilbey, for the guidance and advice along the way. I would also like to express my thanks to my co-supervisor, Dr Jose Perezgonzalez.

I dedicate this thesis to my wife (Michaela) and my two sons (Matthew and Thomas) for their patience throughout the long PhD journey. Their support has always given me the impetus and motivation to complete this undertaking.
Table of Contents

ABSTRACT ..................................................................................................................... ii

ACKNOWLEDGMENTS ............................................................................................ iii

TABLE OF CONTENTS ............................................................................................... iv

TABLES ....................................................................................................................... ix

FIGURES ................................................................................................................... xi

GLOSSARY ............................................................................................................... xii

CHAPTER ONE .............................................................................................................. 1

INTRODUCTION ....................................................................................................... 1
  1.1 The Thesis Context ............................................................................................. 1
  1.2 Study Context ..................................................................................................... 3

CHAPTER TWO............................................................................................................. 8

LITERATURE REVIEW ............................................................................................... 8
  2.1 Chapter Overview ............................................................................................... 8
  2.2 Pilot Licences and Ratings ................................................................................. 8
  2.3 VFR Meteorological Criteria ............................................................................. 10
  2.4 Historical Trends in VFR Flight into IMC Accidents ........................................ 14
  2.5 Primary Cause: Decision Error ......................................................................... 16
    2.5.1 Risk Perception ......................................................................................... 17
    2.5.2 Social and Motivational ............................................................................ 19
    2.5.3 Situational Assessment .............................................................................. 20
  2.6 Cognitive Heuristics and Bias in Decision Making ........................................... 22
    2.6.1 Characteristics of Aeronautical Decision Making .................................... 22
    2.6.2 Cognitive biases in Decision Making ........................................................ 26
  2.7 Cognitive Bias in Weather-Related Decision Making ......................................... 28
    2.7.1 Decision Framing ...................................................................................... 28
    2.7.2 The Sunk Cost Effect ............................................................................... 29
    2.7.3 Optimistic and Ability Bias ....................................................................... 29
  2.8 Cognitive Bias Explored in this Thesis ............................................................... 30
    2.8.1 The Anchoring Effect ............................................................................... 31
    2.8.2 Confirmation Bias ..................................................................................... 34
    2.8.3 Outcome Bias ........................................................................................... 38
  2.9 Research Problem ............................................................................................ 42
  2.10 Research Questions ......................................................................................... 43
CHAPTER FIVE ......................................................................................................... 106
STUDY 3 ...................................................................................................................... 106
OUTCOME BIAS IN VFR FLIGHT INTO IMC AND THE INFLUENCE OF
OUTCOME INFORMATION ON THE DECISION PROCESS ......................... 106
5.1 Introduction .................................................................................................... 106
5.2 Method.......................................................................................................... 110
5.2.1 Participants .............................................................................................. 110
5.2.2 Materials and Design ............................................................................... 111
5.2.3 Dependent Measures ............................................................................... 115
5.2.4 Procedure................................................................................................. 115
5.3 Results ............................................................................................................ 117
5.3.1 General findings ...................................................................................... 117
5.3.2 Decision Judgment .................................................................................. 118
5.3.3 Risk Assessment ...................................................................................... 119
5.3.4 Would Pilots Conduct the Same Flight? ................................................. 120
5.3.5 Correlation ............................................................................................... 121
5.3.6 IR Status .................................................................................................. 122
5.3.7 Age Groups ............................................................................................. 122
5.3.8 Licence Groups ....................................................................................... 122
5.4 Discussion ....................................................................................................... 123

CHAPTER SIX ............................................................................................................ 128
DEBIASING WEATHER-RELATED DECISION MAKING ............................... 128
6.1 Introduction .................................................................................................... 128
6.2 Debiasing Techniques..................................................................................... 129
6.3 Research Problem & Research Questions ...................................................... 133
6.4 Study 4 to 6 Overview .................................................................................... 134

CHAPTER SEVEN ..................................................................................................... 136
STUDY 4 ...................................................................................................................... 136
DEBIASING THE ANCHORING EFFECT IN WEATHER-RELATED
DECISION MAKING ................................................................................................. 136
7.1 Introduction .................................................................................................... 136
7.2 Method.......................................................................................................... 137
7.2.1 Participants .............................................................................................. 137
7.2.2 Material & Design ................................................................................... 138
7.2.3 Procedure................................................................................................. 144
7.3 Results ............................................................................................................ 145
7.3.1 General Findings ..................................................................................... 145
7.3.2 Cloud Height Assessment ....................................................................... 146
10.3.2 Debiasing Weather-Related Decision Making ........................................ 187
10.3.3 Implications of Cognitive Biases in Weather-Related Decision Making 189
10.4 Direction for Future Research ........................................................................ 190
10.5 Limitations ...................................................................................................... 196

CHAPTER ELEVEN .................................................................................................. 197

CONCLUSION ............................................................................................................ 197

REFERENCES ............................................................................................................ 201

APPENDICES ............................................................................................................. 223
Appendix A – Sample of Study 1 Questionnaire ...................................................... 223
Appendix B – Low Risk Ethics Notification for Study 1 ........................................ 235
Appendix C – Sample of Study 2 Questionnaire ..................................................... 236
Appendix D – Low-Risk Ethics Notification for Study 2 .......................................... 243
Appendix E – Sample of Study 3 Questionnaire ..................................................... 244
Appendix F – Low-Risk Ethics Notification for Study 3 .......................................... 256
Appendix G – Sample of Study 4–6 Questionnaire .............................................. 257
Appendix H – Human Ethics Approval for Studies 4–6 ........................................... 274
Appendix I – Debiasing Lecture Slides ................................................................. 275
Tables

Table 1: *The five scenarios and their anchor pairings used in Study 1* ................. 62

Table 2: *Mean assessment of cloud height and horizontal visibility distance by level of anchor* .................................................................................................................................................... 67

Table 3: *Mean safety assessment scores about continuing the VFR flight (1 = not safe, 9 = very safe) by experience level (novice vs. expert) and anchor condition (high vs. low)* ............................................................................................................................................... 69

Table 4: *Mean visibility assessment by licence type (student pilot [SP], private pilot licence [PPL], commercial pilot licence [CPL], air transport pilot [ATPL]) and anchor condition (high vs. low).* .............................................................................................................................................. 71

Table 5: *Evidence used for each scenario in Study 2* ............................................. 90

Table 6: *Characteristics of pilots with and without past experience of VFR flight into IMC* .......................................................................................................................................................... 98

Table 7: *Demographic characteristics of pilots IR status* ......................................... 99

Table 8: *Demographic characteristics of the pilot licence groups* ......................... 100

Table 9: *Negative outcome statements for each scenarios in Study 3* .................... 114

Table 10: *Participants Decision Quality Assessment (1 = very good decision, 9 = very poor decision), Risk Assessment (1 = very low risk, 9 = very high risk) and Assessment of conducting the same VFR flight (1 = safe to conduct flight, 9 = not safe to conduct flight) between outcome condition.* ......................................................................................................................................................... 119

Table 11: *Participants Assessment of conducting the same VFR flight (1 = safe to conduct flight, 9 = not safe to conduct flight) between experience level (novice vs. expert) and outcome conditions.* ......................................................................................................................................................... 121

Table 12: *Pearson’s correlation between the three dependent variables (decision quality, risk assessment, safety assessment).* ......................................................................................................................................................... 121

Table 13: *Four anchor parings by scenario used in Study 4* .................................. 143
Table 14: Cloud Height assessment after exposure to an anchor (high vs. low) and intervention group (debiased vs. control). ................................................................. 147

Table 15: Visibility assessment after exposure to an anchor (high vs. low) and intervention group (debiased vs. control). ................................................................. 148

Table 16: Evidence used in each scenario in Study 5 ................................................................. 158

Table 17: Negative outcome statements for each scenarios in Study 6 ....................... 170
Figures

Figure 1: New Zealand’s VFR Meteorological Minima (CAA NZ, 2015a) ............ 10

Figure 2: Fatality rate for VFR flight into IMC accidents across a range of studies (countries) and time periods. ................................................................. 14

Figure 3: Simplified decision making model (Hutton & Klein, 1999; Madhavan & Lacson, 2006). .......................................................... 24

Figure 4: Characteristics of Type 1 and Type 2 processes in the Dual Process Theory [DPT] of decision making (Kahneman, 2011) ........................................ 28

Figure 5: Comparison of Study 1 pilots to population totals by licence type .... 66

Figure 6: Mean assessment of horizontal visibility distance, by experience level (novice vs. expert) and by anchor condition (high vs. low). ....................... 68

Figure 7: Cloud assessment by age group and anchor condition (high vs. low). .... 72

Figure 8: Comparison of Study 2 pilots to population totals by licence type ...... 95

Figure 9: Comparison of Study 3 pilots to population totals (Australia and USA). 118
# Glossary

The following terms and their corresponding definitions are used in the context of this thesis:

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATPL</td>
<td>Air transport pilot licence: the highest level of aircraft pilot licence. Those certified are authorised to act as the pilot-in-command on larger aircraft that require two pilots to operate.</td>
</tr>
<tr>
<td>CAA NZ</td>
<td>Civil Aviation Authority of New Zealand: the regulatory authority of civil aviation in New Zealand.</td>
</tr>
<tr>
<td>CASA</td>
<td>Civil Aviation Safety Authority: the Australian national aviation authority (i.e., the government statutory authority responsible for the regulation of civil aviation).</td>
</tr>
<tr>
<td>CPL</td>
<td>Commercial pilot licence: a qualification that permits the holder to act as a pilot of an aircraft and be paid for his/her work. The pilot may also act as a co-pilot (first officer) of an aircraft that requires two pilots to operate.</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration: the regulatory authority of civil aviation in the United States.</td>
</tr>
<tr>
<td>GA</td>
<td>General aviation: aircraft operating on non-commercial flights. Aircraft of a variety of sizes can operate in GA, with four- to six-seater aircraft (e.g., a Cessna 172 with four seats) being a relatively common aircraft type</td>
</tr>
<tr>
<td>IFR</td>
<td>Instrument flight rules: regulations and procedures for flying aircraft by referring only to the aircraft instrument panel for navigation.</td>
</tr>
<tr>
<td>IR</td>
<td>Instrument rating: the qualifications that a pilot must have in order to fly under IFR.</td>
</tr>
<tr>
<td>IMC</td>
<td>Instrument meteorological conditions: meteorological conditions expressed in terms of visibility, distance from cloud and ceiling less than the minima specified for visual meteorological conditions.</td>
</tr>
<tr>
<td><strong>NTSB</strong></td>
<td>National Transportation Safety Board: an independent United States government investigative agency responsible for civil transportation accident investigation.</td>
</tr>
<tr>
<td><strong>PIC</strong></td>
<td>Pilot-in-command: in relation to any aircraft, means the pilot responsible for the operation and safety of the aircraft</td>
</tr>
<tr>
<td><strong>PPL</strong></td>
<td>Private pilot licence: a licence that permits the holder to act as the pilot-in-command of an aircraft privately (not for pay).</td>
</tr>
<tr>
<td><strong>SP</strong></td>
<td>Student pilot: someone who does not hold a pilot licence but is often in the training phase under supervision. They may fly solo without passengers provided they meet the required criteria (e.g., a valid medical certificate).</td>
</tr>
<tr>
<td><strong>TSB</strong></td>
<td>Transport Safety Board of Canada (officially the Canadian Transport Accident Investigation and Safety Board): the agency of the Government of Canada responsible for maintaining transportation safety in Canada.</td>
</tr>
<tr>
<td><strong>VMC</strong></td>
<td>Visual meteorological conditions: the meteorological conditions expressed in terms of visibility, distance from cloud and ceiling equal to or better than specified minima:</td>
</tr>
<tr>
<td><strong>VFR</strong></td>
<td>Visual flight rules: a set of aviation regulation under which a pilot may operate an aircraft in weather conditions that are sufficient to allow the pilot, by visual reference to the environment outside the cockpit, to control the aircraft’s attitude, navigate and maintain safe separation from obstacles such as terrain, buildings and other aircraft.</td>
</tr>
</tbody>
</table>