THE PREVALENCE AND ROLE OF ALCOHOL, MARIJUANA, BENZODIAZEPINES AND STIMULANTS IN DRIVERS INJURED IN ROAD CRASHES

Marie Cristiana Longo

B.A. (Hons.)

Thesis submitted for the degree of

Doctor of Philosophy (Ph.D.)

in the

Department of Clinical and Experimental Pharmacology

Faculty of Health Sciences

Adelaide University

October 2001

"Canst that thou not minister to a mind diseased,
Pluck from the memory a rooted sorrow,
Raze out the written troubles of the brain,
And with some sweet oblivious antidote
Cleanse the stuff'd bosom of that perilous stuff
Which weighs upon the heart?"
SHAKESPEARE - *Timon of Athens: Act IV, Scene 3.*

TABLE OF CONTENTS

LIST OF TABLES ix

LIST OF FIGURES xiii

ABSTRACT xv

DECLARATION xix

PUBLICATIONS IN SUPPORT OF THIS THESIS xx

CONFERENCE PAPERS AND PRESENTATIONS xxi

SCHOLARSHIPS AND GRANTS xxii

ACKNOWLEDGEMENTS xxiii

LIST OF ABBREVIATIONS xxv

CHAPTER 1: INTRODUCTION 1

1.1 The history and general effects of alcohol, marijuana, benzodiazepines and stimulants 2

1.1.1 General mechanisms of action 2

1.1.2 Alcohol 3

1.1.3 Marijuana 6

1.1.4 Benzodiazepines 9

1.1.5 Stimulants 10

1.2 Experimental studies 13

1.2.1 Studies using psychophysiological tests 16

1.2.1.1 Alcohol 17

1.2.1.2 Marijuana 18

1.2.1.3 Benzodiazepines 20

1.2.1.4 Stimulants 22

1.2.1.5 Alcohol and marijuana 23

1.2.1.6 Alcohol and benzodiazepines 24

1.2.1.7 Alcohol and stimulants 24

1.2.1.8 Other drug combinations 25

1.2.2 Studies using driving simulators 25

1.2.2.1 Alcohol 27

1.2.2.2 Marijuana 28

1.2.2.3 Benzodiazepines 29
1.2.2.4 Stimulants 31
1.2.2.5 Alcohol and other drugs 31
1.2.3 Studies of driving performance on roads 33
1.2.3.1 Alcohol 36
1.2.3.2 Marijuana 37
1.2.3.3 Benzodiazepines 38
1.2.3.4 Stimulants 39
1.2.3.5 Alcohol and other drugs 39
1.3 Epidemiological studies 41
1.3.1 Uncontrolled studies 41
1.3.1.1 Alcohol 42
1.3.1.2 Marijuana 45
1.3.1.3 Benzodiazepines and stimulants 46
1.3.2 Case-control studies 46
1.3.2.1 Alcohol 47
1.3.2.2 Marijuana 49
1.3.2.3 Benzodiazepines 49
1.3.2.4 Stimulants 51
1.3.3 Summary 52
1.4 Studies of culpability/responsibility 52
1.4.1 Methods of assessing culpability 53
1.4.2 Results of culpability studies 55
1.4.2.1 Gender and age of drivers 55
1.4.2.2 Alcohol 55
1.4.2.3 Marijuana 56
1.4.2.4 Benzodiazepines 59
1.4.2.5 Stimulants 59
1.4.2.6 Alcohol and marijuana 60
1.4.2.7 Alcohol and benzodiazepines 60
1.4.2.8 Alcohol and stimulants 61
1.4.3 Summary 61
1.5 Aims of the present study 62

1.5.1 Rationale 62
1.5.2 Specific aims and hypotheses 65
CHAPTER 2: METHODS 68
2.1 Sample selection and procedure 68
2.2 Drug analyses 69
2.2.1 General information 70
2.2.2 Screening methods 70
2.2.3 Drug identification and quantification methods 71
2.3 Culpability analysis 74
2.4 Statistical analyses 75
CHAPER 3: DRUG PREVALENCE 76
3.1 Introduction 76
3.2 Methods 77
3.3 Results 78
3.3.1 Prevalence of drug use 78
3.3.2 Characteristics of the drug-positive group 83
3.3.2.1 Gender and age 83
3.3.2.2 Type of vehicle involved 88
3.3.2.3 Single and multiple vehicle crashes 89
3.3.2.4 Time and location of the crash 90
3.4 Discussion 92
CHAPER 4: DRUG USE AND CULPABILITY 97
4.1 Introduction 97
4.2 Methods 100
4.3 Results 101
4.3.1 Culpability rates 101
4.3.2 Gender and age 102
4.3.3 Number and type of vehicles involved 103
4.3.3.1 Car drivers 104
4.3.3.2 Motorcycle riders 105
4.3.4 Drug prevalence and culpability 105
4.3.5 Drug concentration and culpability 107

4.3.5.1 Alcohol 107
4.3.5.2 Alcohol and culpability after controlling for age 109
4.3.5.3 THC 110
4.3.5.4 THC and culpability after controlling for age 111
4.3.5.5 Benzodiazepines 112
4.3.5.6 Benzodiazepines and culpability after controlling for age 114
4.3.5.7 Stimulants 114
4.3.5.8 Alcohol and THC 116
4.3.5.9 Alcohol and benzodiazepines 116
4.3.6 Comparison with fatally injured drivers 117
4.3.6.1 Demographic and crash characteristics 117
4.3.6.2 Drug prevalence 117
4.3.6.3 Culpability 120
4.4 Discussion 121
CHAPTER 5: ESTIMATES OF DRUG CONCENTRATION 130
5.1 Introduction 130
5.2 Methods 132
5.2.1 Back-calculations for alcohol 132
5.2.2 Back-calculations for THC 132
5.2.3 Back-calculations for benzodiazepines 134
5.2.4 Back-calculations for stimulants 135
5.3 Results 137
5.3.1 Alcohol 137
5.3.2 THC 139
5.3.3 Benzodiazepines 141
5.4 Discussion 143
CHAPTER 6: RECIDIVISM 146
6.1 Introduction 146
6.1.1 The incidence of drink-driving recidivism 147
6.1.2 Drink-driving recidivism and traffic offences 148
6.1.3 Drink-driving recidivism and drug prevalence 149
6.2 Methods 150

6.3 Results 151

6.3.1 Blood alcohol concentrations 151

6.3.2 Characteristics of inclusive drink-driving recidivists 151

6.3.3 Prior drink-driving recidivism and culpability 154

6.3.4 Prior drink-driving recidivism and BAC in the crash 155

6.3.5 Length of time between drink-driving convictions 158

6.3.6 Inclusive drink-driving recidivism and other traffic offences 160

6.3.6.1 Speeding 160

6.3.6.2 Reckless/dangerous driving or driving without due care 161

6.3.6.3 Other traffic offences 163

6.3.6.4 Criminal offences 164

6.3.7 Prior drink-driving recidivism and drug prevalence 165

6.4 Discussion 167

CHAPTER 7: MISSING DATA 171

7.1 Introduction 171

7.2 Methods 172

7.3 Results 174

7.3.1 Comparison of matched and unmatched cases 174

7.3.2 Comparison of a sub-set of matched and unmatched cases attending the Royal Adelaide Hospital 178

7.3.2.1 Summary of RAH data 182

7.3.3 Comparison of a sub-set of matched and unmatched cases attending rural hospitals 182

7.4 Discussion 187

CHAPTER 8: STORAGE OF THC 190

8.1 Introduction 190

8.2 Methods 192

8.3 Results 192

8.4 Discussion 198

CHAPTER 9: DISCUSSION 200

BIBLIOGRAPHY 216

APPENDIX A: CULPABILITY ANALYSIS GUIDELINES 339

APPENDIX B:	**ADDITIONAL VARIABLES**	342
APPENDIX C:	**THE PHARMACOLOGY OF THC**	348
APPENDIX D:	**MARIJUANA CONCENTRATIONS**	361
APPENDIX E:	**BENZODIAZEPINE CONCENTRATIONS**	366
APPENDIX F:	**HOSPITAL RECORDING SCHEDULE**	372
APPENDIX G:	**CASE SUMMARIES OF RURAL UNMATCHED DRIVERS**	376
APPENDIX H:	**STORAGE OF MARIJUANA**	378

LIST OF TABLES

Table 1:	Concentration ranges for benzodiazepines in whole blood, plasma or serum	73
Table 2:	Concentration ranges for stimulants in whole blood, plasma or serum	74
Table 3:	Percentage of injured drivers testing positive for each drug and drug combination	79
Table 4:	Blood alcohol concentrations of injured drivers	80
Table 5:	THCA concentrations of injured drivers	80
Table 6:	THC concentrations of injured drivers	80
Table 7:	Percentage of injured drivers testing positive for each type of benzodiazepine	81
Table 8:	Percentage of injured drivers testing positive for each type of stimulant	83
Table 9:	Percentage of injured drivers testing positive for drugs by age	84
Table 10:	Percentage of injured drivers testing positive for each drug and drug combination by gender	84
Table 11:	Percentage of injured drivers testing positive for each drug and drug combination by gender and age	86
Table 12:	Percentage of injured drivers in each BAC category by gender	86
Table 13:	Percentage of injured drivers in each BAC category by gender and age	87
Table 14:	Percentage of injured drivers testing positive for each drug and drug combination by the type of vehicle in the crash	88
Table 15:	Percentage of injured drivers in each BAC category by the type of vehicle in the crash	89
Table 16:	Percentage of injured drivers testing positive for each drug and drug combination by the number of vehicles in the crash	90
Table 17:	Percentage of injured drivers testing positive for each drug and drug combination by the time of the crash	91

Table 18:	Percentage of injured drivers testing positive for each drug and drug combination by the location of the crash	91
Table 19:	Culpability for the crash	102
Table 20:	Percentage of injured car drivers judged culpable by the drug combination and number of vehicles involved	104
Table 21:	Percentage of injured riders judged culpable by the drug combination and number of vehicles involved	105
Table 22:	Percentage of injured car drivers and riders testing positive for each drug and drug combination by the level of culpability for the crash	106
Table 23:	Culpability of injured drivers and BAC: alone or in combination with other drugs	108
Table 24:	Culpability of injured drivers and THC concentration: alone or in combination with other drugs	111
Table 25:	Culpability of injured drivers and benzodiazepine level: alone or in combination with other drugs	113
Table 26:	Culpability of injured drivers and stimulant level: alone or in combination with other drugs	115
Table 27:	Comparison of drug prevalence for fatally and non-fatally injured drivers	118
Table 28:	Distribution of culpability for fatally and non-fatally injured drivers	121
Table 29:	Comparison of culpability rates for fatally and non-fatally injured drivers	121
Table 30:	C_{max} values and plasma to whole blood ratios for benzodiazepines	136
Table 31:	Culpability of injured drivers and estimated BAC at the time of the crash: alone or in combination with other drugs	138
Table 32:	Culpability of injured drivers and estimated plasma THC concentration at the time of the crash using 100 minute half-life: alone or in combination with other drugs	140
Table 33:	Culpability of injured drivers and estimated benzodiazepine concentration expressed as a percentage of the C_{max}: alone or in combination with other drugs	142
Table 34:	Number of drink-driving convictions recorded by injured drivers	152

Table 35:	Mean age and gender distribution of injured drivers with drink-driving convictions	152
Table 36:	Number of drink-driving convictions by the type of vehicle in the crash	153
Table 37:	Number of drink-driving convictions by the number of vehicles in the crash	153
Table 38:	Licence status of injured drivers at the time of the crash by the number of drink-driving convictions, including the conviction at the time of the crash	154
Table 39:	Culpability of injured drivers by the number of drink-driving convictions, excluding the conviction at the time of the crash	155
Table 40:	BAC of injured drivers at the time of the crash by the number of prior drink-driving convictions, excluding the conviction at the time of the crash	156
Table 41:	The percentage of injured drivers in each BAC category with prior drink-driving convictions, excluding the conviction at the time of the crash	158
Table 42:	Length of time between drink-driving convictions for injured drivers with two convictions	159
Table 43:	Length of time between drink-driving convictions for injured drivers with three convictions	159
Table 44:	Percentage of injured drivers with speeding offences by the number of drink-driving convictions	161
Table 45:	Percentage of injured drivers with 'reckless/dangerous driving' or 'driving without due care' offences by the number of drink-driving convictions	162
Table 46:	Percentage of injured drivers with other traffic offences by the number of drink-driving convictions	164
Table 47:	Miscellaneous traffic offences	165

Table 48:	Percentage of injured drivers testing positive for drugs by the number of drink-driving convictions, excluding the conviction at the time of the crash	166
Table 49:	BAC distributions of matched and unmatched cases	174
Table 50:	Drink-driving convictions of matched and unmatched cases	175
Table 51:	Licence status of matched and unmatched cases	176
Table 52:	Prevalence of drugs in matched and unmatched cases	177
Table 53:	BAC distributions of RAH matched and unmatched cases	179
Table 54:	Drink-driving convictions of RAH matched and unmatched cases	180
Table 55:	Licence status of RAH matched and unmatched cases	180
Table 56:	Prevalence of drugs in RAH matched and unmatched cases	181
Table 57:	Hospital attended for rural matched and unmatched cases	183
Table 58:	BAC distributions of rural matched and unmatched cases	184
Table 59:	Drink-driving convictions of rural matched and unmatched cases	185
Table 60:	Licence status of rural matched and unmatched cases	185
Table 61:	Prevalence of drugs in rural matched and unmatched cases	186
Table 62:	Initial concentrations of THC and THCA	193

LIST OF FIGURES

Figure 1:	The processes involved in matching hospital and crash data	69
Figure 2:	Gender distribution of injured drivers for each drug and drug combination	85
Figure 3:	Gender distribution of BACs in injured drivers	87
Figure 4:	The distribution of culpability by gender and age group	103
Figure 5:	Culpability rates of injured car drivers and riders for each drug and drug combination	107
Figure 6:	Culpability of injured drivers and blood alcohol concentration	109
Figure 7:	Culpability of injured drivers and THC concentration	111
Figure 8:	Culpability of injured drivers and benzodiazepine level	113
Figure 9:	Culpability of injured drivers and stimulant level	115
Figure 10:	Prevalence of drugs in fatally and non-fatally injured drivers	119
Figure 11:	BAC distributions of fatally and non-fatally injured drivers	120
Figure 12:	Distribution of the time-delay between crash and blood sample collection	137
Figure 13:	Relative risk of culpability for injured drivers and BAC: alcohol used alone	139
Figure 14:	Relative risk of culpability for injured drivers and THC concentration: THC used alone	141
Figure 15:	Relative risk of culpability for injured drivers and benzodiazepine concentration: benzodiazepines used alone	143
Figure 16:	BAC distributions of injured drivers with drink-driving convictions	157
Figure 17:	Prevalence of drugs in injured drivers with drink-driving convictions	167
Figure 18:	BAC distributions of matched and unmatched cases	175
Figure 19:	Prevalence of drugs in matched and unmatched cases	177

Figure 20: Change in THC concentration over time after storage in silanised glass tubes 195
Figure 21: Change in THC concentration over time after storage in polycarbonate plastic tubes 195
Figure 22: Change in THC concentration over time after storage in polypropylene plastic tubes 196
Figure 23: Change in THCA concentration over time after storage in silanised glass tubes 196
Figure 24: Change in THCA concentration over time after storage in polycarbonate plastic tubes 197
Figure 25: Change in THCA concentration over time after storage in polypropylene plastic tubes 197

ABSTRACT

The main aim of this study was to examine the relationship between drug use and culpability in a sample of drivers who were injured in road crashes. Four drugs/drug classes were chosen for analysis based on the prevalence of their use and the likelihood of their playing a role in crashes: alcohol, marijuana (measured by the presence of Δ^9tetrahydrocannabinol [THC] or its metabolite, 11-nor-Δ^9tetrahydrocannabinol-9-carboxylic acid [THCA]), benzodiazepines and stimulants. Blood samples were obtained from 2898 injured drivers. The relationship between the presence and concentration of these drugs and the culpability of the driver was examined using objective scoring criteria to assess culpability. The data collected were analysed to determine the effects of each drug, both alone and in combination with other drugs, and whether concentration was a determining factor. In 398 cases (13.7%) the blood sample was unable to be matched with a police crash report to obtain demographic and crash information. However, detection rates for drugs within these 'unmatched' cases were not exceptional and their inevitable exclusion from these analyses did not bias the results in any way. The final sample of 2500 drivers used in this study thus comprises a representative sample of injured drivers in South Australia.

Overall, three-quarters of drivers were drug-free. Alcohol was the most frequently detected drug. Marijuana was also detected at high rates, but the majority of drivers tested positive for THCA, the inactive metabolite of THC. Benzodiazepines and stimulants were detected at low rates, as were combinations of two or more drugs. Males were more likely to test positive for drugs, especially alcohol and THC, whereas females were more likely to test positive for benzodiazepines. A similar proportion of car drivers and motorcycle riders tested positive for drugs although riders were more likely to test positive for THC. Car drivers involved in single-vehicle crashes were more likely to test positive for drugs than car drivers in multiple-vehicle crashes, in particular for alcohol alone, THC alone and alcohol in combination with either THC or benzodiazepines. Riders were also more likely to test positive for alcohol alone in single-vehicle crashes, but there was a higher prevalence of THC alone in multiple-vehicle crashes.

There were no significant differences between the culpability rates of males and females. However, there was a relationship between age and culpability with drivers below 26 years and above 60 years more likely to be culpable. Drivers who tested positive for alcohol alone or benzodiazepines alone were significantly more likely to be culpable for the crash compared with drug-free drivers. In contrast, a lower percentage of drivers who tested positive for THC alone were culpable for the crash compared with drug-free drivers, although this difference was not statistically significant. The relationship between stimulants and culpability was also non-significant, although a higher proportion of stimulant-positive drivers were culpable compared with drug-free drivers. The combinations of alcohol and THC, and alcohol and benzodiazepines produced a significant increase in culpability but this was not significantly greater than that produced by alcohol alone.

The majority of car drivers in single-vehicle crashes were judged culpable irrespective of drug use. In multiple-vehicle crashes, car drivers testing positive for alcohol alone or benzodiazepines alone were more likely to be culpable for the crash compared with drug-free drivers. For riders in both single- and multiple-vehicle crashes, there were no significant differences between the drug-positive and drug-free groups, although riders who tested positive for THC alone had a lower culpability rate than the drug-free riders.

Analyses were also performed to examine the relationship between drug concentration and culpability. There was a significant concentration-dependent relationship between alcohol and culpability: as blood alcohol concentration increased, so did the percentage of culpable drivers. There was also a significant relationship between benzodiazepine concentration and culpability. Amongst those drivers with benzodiazepine concentrations that were at or above therapeutic levels, culpability rates were significantly higher compared with drug-free drivers. The relationship between THC concentration and culpability was not significant, although there was a trend for decreased culpability at lower concentrations, and an increase at higher concentrations. The number of drivers who tested positive for stimulants was too small to examine the effects of concentration.

A possible limitation in this study was the time-delay between the crash and blood sample collection. As blood concentrations of drugs change over time this can

potentially confound interpretation of the data, especially where there is a substantial delay. Drug concentrations at the time of the crash were estimated for alcohol and THC using pharmacological data on concentration-time relationships for these drugs. The relationship between drug use and culpability was then re-analysed. For benzodiazepines, the concentrations of the different drugs in this class were converted to a single scale, which allowed the relationship between concentration and culpability to be examined in the same way as for alcohol and THC. This was not done for stimulants as only a small number of drivers tested positive. In addition, previous results had revealed a significant relationship between age and culpability in this sample. Consequently, culpability rates between drug-positive and drug-free drivers were compared using age-matched controls from the drug-free group in order to control for differences in culpability that may have been due to age. Overall, the relationships between drugs and culpability reported previously did not change after estimating the concentration at the time of the crash, and using age-matched controls.

Analyses were also performed to investigate the effects of long-term storage of blood samples on the accuracy of the marijuana concentrations reported in this study. Samples from eight deceased persons suspected of using marijuana were stored in three types of containers and THC concentrations were monitored for up to 15 months. Although there was found to be a significant overall decrease in THC concentrations over the storage period, these concentrations did not disappear completely. It is unlikely that any THC-positive samples in the present study were not detected, and thus the results reported in this study were not compromised by long-term storage of the blood samples.

Additional analyses were carried out on the data to further examine the characteristics of these crash-involved drivers, and to investigate factors other than drug use that could predict crash culpability. Drivers' drink-driving and traffic offence histories prior to the crash were obtained. A profile of recidivist drink-drivers was established, and the relationship between prior drink-driving offences and crash culpability was explored. The recidivist drink-drivers tended to be male, with a mean age of 31.7 years. Compared with drivers with no drink-driving convictions, recidivists were more likely to have an aberrant traffic offence history with a high incidence of offences including speeding and dangerous driving, as well as driving without a valid licence. First-time

drink-driving offenders shared many of the same characteristics as recidivists. These drivers were also predominantly male, with a mean age of 29.6 years, and had a higher incidence of traffic offences than drivers with no drink-driving convictions. The study also examined whether having prior convictions for drink-driving could predict the likelihood of drivers being culpable for their crash. Drivers with one or more prior drink-driving convictions were significantly more likely to have been culpable for the crash than drivers with no prior convictions. They were also more likely to test positive for alcohol, either alone or in combination with other drugs, and particularly to record high BACs. Thus, having prior drink-driving convictions was a good predictor of both culpability in the crash and testing positive for drugs.

The results of this study found a clear link between alcohol and culpability. Injured drivers who tested positive for alcohol were significantly more likely to be culpable and the effect was stronger at higher BACs. This confirms past research in highlighting the overwhelming prevalence of alcohol in injured drivers compared with other drugs, as well as its dominant role in road crashes. A significant relationship was also found between the use of benzodiazepines and culpability. Amongst those with benzodiazepine concentrations that were at or above therapeutic levels, culpability was significantly greater than for the drug-free group. This has been the first study to show a significant effect of benzodiazepines when used alone, at concentrations that fell within the therapeutic range. In contrast, there was no significant effect of either THC or stimulants on culpability. Although a large number of injured drivers tested positive for THC alone (a similar number to benzodiazepines, for which an effect was observed), their culpability rate was no higher than that of drug-free drivers. Relatively few drivers tested positive for stimulants other than pseudoephedrine, which has weak stimulant effects, and in many cases they were found at low concentrations. Given the low detection rates and the evidence that at least some drivers were not culpable, it is reasonable to conclude that stimulants do not play a major role in road crashes.

DECLARATION

This work contains no material which has been accepted for the award of any other degree or diploma in any university or tertiary institution, and to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University library, being available for loan and photocopying.

SIGNED:..... DATE:.....

PUBLICATIONS IN SUPPORT OF THIS THESIS

Chesher, G.B. & Longo, M.C. (2001). Cannabis and Driving. In *Cannabis and Cannabinoids: Pharmacology, Toxicology and Therapeutic Potential.* USA: Haworth Press, Chapter 28.

Hunter, C.E., Lokan, R.J., Longo, M.C., White, J.M. & White, M.A. (1998). *The prevalence and role of alcohol, cannabinoids, benzodiazepines and stimulants in non-fatal crashes.* South Australia: Forensic Science, Department for Administrative and Information Services.

Longo, M.C., Hunter, C.E., Lokan, R.J., White, J.M. & White, M.A. (2000a). The Prevalence of Alcohol, Cannabinoids, Benzodiazepines and Stimulants amongst injured drivers and their role in driver culpability. Part I: the prevalence of drug use in drivers, and characteristics of the drug positive group. *Accident Analysis and Prevention, 32(5),* 613-622.

Longo, M.C., Hunter, C.E., Lokan, R.J., White, J.M. & White, M.A. (2000b). The Prevalence of Alcohol, Cannabinoids, Benzodiazepines and Stimulants amongst injured drivers and their role in driver culpability. Part II: the relationship between drug prevalence and drug concentration, and driver culpability. *Accident Analysis and Prevention, 32(5),* 623-632.

Longo, M.C., White, J.M., Lokan, R.J. & Hunter, C.E. (2000c). *A re-analysis of the relationship between drug concentration and culpability for non-fatal crashes using estimates of drug concentration at the time of the crash.* South Australia: Safety Strategy Section, Transport SA. Report Number 2/2000.

Longo, M.C., White, J.M., Lokan, R.J. & Hunter, C.E. (2000d). *Drink-driving recidivism and traffic offence histories of drivers involved in non-fatal crashes in South Australia.* South Australia: Safety Strategy Section, Transport SA. Report Number 3/2000.

Longo, M.C. (2000). *Cannabis, alcohol and crash risk.* Paper prepared for the Nova Institute, Cologne, Germany.

Longo, M.C., Lokan, R.J. & White, J.M. (2001). The relationship between benzodiazepine concentration and vehicle crash culpability. *Journal of Traffic Medicine, 29(1-2),* 36-43.

Longo, M.C. & O'Connor, P. J. (2001). *An investigation of discrepancies between police crash data and hospital data in metropolitan and rural hospitals*. South Australia: Safety Strategy Section, Transport SA, Internal Report.

CONFERENCE PAPERS AND PRESENTATIONS

South Australian drivers involved in non-fatal crashes: how many are drink driving recidivists? Presented at the Drink Driving Recidivism Summit, Adelaide, Australia, 26-27 November 1996.

The role of alcohol, cannabinoids, benzodiazepines and stimulants in road crashes. Presented at the Road Safety Research Policing and Education Conference, Canberra, Australia, 28-30 November 1999.

The role of alcohol, cannabinoids, benzodiazepines and stimulants in road crashes. Presented at the 15th International Conference on Alcohol, Drugs and Traffic Safety, Stockholm, Sweden, 22-26 May 2000.

Drugs and driving: how is South Australia compared to international best practice? Presented at the RAA Road Safety Summit, Adelaide, Australia, 2 November 2000.

SCHOLARSHIPS AND GRANTS

Federal Office of Road Safety Postgraduate Scholarship awarded April 1998.

Postgraduate Travelling Fellowship for Biomedical Research awarded December 1999.

Grant obtained from Transport SA in January 2001 to undertake a project entitled *"An investigation of identified discrepancies between police crash data and hospital separation data in rural hospitals*".

ACKNOWLEDGEMENTS

An owl is sitting in a tree in the forest, watching what is happening around him. He observes a rabbit sitting under a neighbouring tree, typing furiously on a lap-top computer. Intrigued, the owl flies over to the tree and asks the rabbit what she is doing. The rabbit, looking rather stressed, replies that she is writing her Ph.D. The owl asks the rabbit what her topic is. The rabbit's expression lights up, and she eagerly explains that she is testing the hypothesis that she, although a defenceless rabbit, is immune to danger from larger, more ferocious animals. The owl looks skeptical, and asks the rabbit to explain further. The rabbit jumps up and says "I'll do better than that, I'll prove it to you. See that lion over there? I will approach him, and I will not come to any harm". So off goes the rabbit, while the owl looks on in dismay, certain that his new friend is about to become lunch. But to his amazement, the rabbit leads the lion off into a nearby cave. The lion emerges only seconds later, with a look of utter fear on his face, and runs off into the forest, closely followed by the rabbit, who now has a rather smug expression on her face. The bewildered owl yells "How on earth did you manage THAT??" The rabbit replies "That's nothing, watch this". The rabbit then wanders over to a bear that is lying under another tree, sleeping. Once again, the rabbit leads the bear off to the cave, and once again the bear emerges only seconds later, this time with tears pouring down his face. The owl is now completely confused, and demands to know how the rabbit is achieving this. The rabbit, torn between protecting her results and a desire to boast, motions the owl over to the cave. Full of trepidation, but curious to solve the mystery, the owl follows the rabbit inside. Sitting in an armchair is a large dragon, wearing glasses and reading a book. He looks up as the pair enters, and immediately fire erupts from his mouth. The last words the owl hears as he is fleeing the cave in terror are "You see, it doesn't matter what your thesis topic is, as long as you have a good supervisor you will be successful".

This rather long-winded story is my way of sincerely thanking my supervisor, Professor Jason White, for all his help, advice and guidance over the last four years. Jason has encouraged and supported me throughout my Ph.D., and convinced me that the light at the end of the tunnel does, in fact, exist.

I have spent four years of my life working on this thesis, and there were times when I thought it would never be finished! So many people have been there for me on this long journey, and I want to take this opportunity to thank each and every one of them.

- ☺ All the staff and students in the Department of Clinical and Experimental Pharmacology at Adelaide University for their help and support;
- ☺ Dr Michael White, Mr John Spencer and Ms Christine Hunter from the Safety Strategy Section of Transport SA for supporting this project from start to finish;
- ☺ Dr Robert Lokan from Forensic Science for analysing the blood samples, and always being available to answer my questions;
- ☺ Ms Pam Dearden and Ms Santina Luppino from Transport SA, and Ms Maryanne Harris from SAPOL for helping me access police crash reports;
- ☺ Ms Robyn Johns, Ms Angela Slagter and Mr Harry McDonald from the Registration and Licencing section of Transport SA for helping me access traffic offence histories;
- ☺ Mr Peter O'Connor from the National Injury Surveillance Unit at Flinders University for his advice and support;
- ☺ Dr Greg Chesher and Dr John Bailey for all their help and advice;
- ☺ All the librarians at the Road Accident Research Unit Library and the Barr Smith Library for obtaining the hundreds of articles and reports I needed to read;
- ☺ The administrative and medical records staff at the Royal Adelaide Hospital and at the 17 rural hospitals who helped me access the patient case notes;
- ☺ Ms Kristyn Willson for her statistical help and advice;
- ☺ Ms Adrienne Gorringe from the Scholarships office at Adelaide University.

Special thanks to the Australian Transport Safety Bureau (formerly the Federal Office of Road Safety) for providing me with a Road Safety Postgraduate Scholarship to undertake this research. In particular, I wish to thank Dr Michael McFadden and Mr Jim Wylie.

Last, but definitely not least, thank you to my wonderful parents Don and Lyn Longo, and my sister and brother Lara and Tom for all their support and understanding, and for knowing when to keep away!! I could not have done this without them. Thanks also to all my friends who listened to me complain, and made sure I relaxed occasionally and got away from my computer!!

LIST OF ABBREVIATIONS

BAC	blood alcohol concentration
CR	culpability ratio (proportion of drivers who were culpable was calculated for the various drug groups including the drug-free group)
GABA	gamma-aminobutyric acid
GC	gas chromatography
HPLC	high pressure liquid chromatography
MDA	methylenedioxyamphetamine
MDEA	methylenedioxyethylamphetamine
MDMA	methylenedioxymethamphetamine
NMDA	n-methyl-d-aspartate
OR	odds ratio (measure of relative risk: obtained by dividing the culpability ratio of a drug group by the culpability ratio of the drug-free group)
SD	standard deviation
SDLP	standard deviation of lateral position
THC	Δ^9tetrahydrocannabinol
THCA	11-nor-Δ^9tetrahydrocannabinol-9-carboxylic acid