

# Alcohol and Energy Drinks in NSW: Research

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Energy drinks and energy 'shots' have become increasingly popular in recent years. Many people consume them with the belief that the beverage will assist in endurance, concentration and stamina.

To better understand any potential for harm when young people drink alcohol and energy drinks together, NSW Health commissioned independent research. The Turning Point Drug and Alcohol Centre in Victoria led a research consortium which comprised Australia's top researchers. The research study included:

- an online survey of 16-35 year olds in NSW to determine how common consumption of combined alcohol and energy drink is, target group most affected, characteristics of use and harms of use
- a street intercept face-to-face survey of 16-35 year olds in NSW conducted at night times in several Sydney metropolitan sites and Orange and Newcastle
- a lab-based experiment to test the effects of combining alcohol and energy drinks on the body, coordination and risk-taking behaviour.

The outcome was a good first step in looking at this issue in the Australian setting. The lab-based research undertaken by the consortium has added real knowledge about the body's response to combined alcohol and energy drinks.

Use of alcohol and energy drinks is an emerging issue and a very difficult area to research effectively. As a consequence, caution is needed in interpreting and acting on any findings. The surveys, while containing some unavoidable methodological constraints, provide some consistent social findings. Given the difficult nature of research in this area, these findings cannot easily be generalised to the NSW population and cannot be solely used as a basis for regulatory or other interventions

## **Key Findings**

The surveys found that mixing alcohol with energy drinks is a popular practice among young people in NSW and particularly in public places such as licensed venues and music festivals. The researchers found that people who combine consumption of alcohol and energy drinks may already be risk takers. These people were more likely to consume more alcohol or illicit drugs, as well as be more involved in aggressive incidents than people who do not combine consumption of alcohol and energy drinks.

The surveys also found that during sessions of alcohol and energy drink use symptoms included racing heart/heart palpitations, insomnia, energy fluctuations, and nausea.

In the day(s) following sessions of alcohol and energy drink use, symptoms included visual disturbances, nausea, and fatigue. These symptoms are consistent with caffeine toxicity, and many are also consistent with alcohol toxicity.

The researchers outlined a number of recommendations relating to health promotion activities, licensed premises, data monitoring, and research. While there are anecdotal reports on what combining alcohol and energy drinks may do to an individual, there is not yet a rigorous body of conclusive scientific evidence.

The Ministry will work across government and with industry on how to incorporate this research information into existing responsible drinking strategies and campaigns such as *Your Room* website; *What are you doing to yourself*, and *Know when to say when*.

A number of the recommended actions in the report are more appropriately dealt with at the national level. These relate to policy of product labeling; caffeine standards; national surveys and research. The NSW Ministry of Health will refer these matters to the Commonwealth Government and to the relevant national forums for further consideration.

A copy of the report may be accessed at [www.health.nsw.gov.au](http://www.health.nsw.gov.au)

### **Important Information for Young People**

It is important for young people to know and understand the information that manufacturers put on product labels – whether alcohol, energy drinks or other beverages. Young people need to be alert to any recommended consumption levels to avoid unnecessary health problems.

The NSW Ministry of Health continues to encourage individuals to be careful about what they are drinking when they are partying:

- Drink water between alcoholic drinks
- Be careful how many rounds or shots you drink
- Watch your drink – drink spiking, including double shots, happens mostly in homes or at parties by someone you know
- Take notice of warnings on cans or recommended levels of consumption to avoid drinking either energy drinks or other caffeinated drinks at levels that could harm your health.
- Look after your mates and always tell them where you are going and with whom
- Never drive if you have been drinking.



# **Alcohol and Energy Drinks in NSW**

**Leading responses to alcohol and drug issues**

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A REPORT PREPARED FOR NSW HEALTH

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## LIST OF TABLES

Table 1. Ingredient composition of primary EDs marketed in Australia per 250mL.....	17
Table 2. Percentage of ED users in university student and community samples.....	20
Table 3. The effect of ED ingestion on simple, choice, and recognition reaction time and accuracy... 23	
Table 4. The effect of ED ingestion on heart rate and systolic, diastolic, and mean arterial blood pressure .....	28
Table 5. Percentage of AED users in university student and community samples .....	32
Table 6. Self-reported motivations for AED use in order of frequency .....	38
Table 7. Self-reported side-effects experienced from AED use in order of frequency .....	45
Table 8. Number of exposures according to the type of co-ingested substance (n=14) .....	58
Table 9. Demographic and exposure characteristics of the AED-only recreational exposure subsample (n=18) and AED and other substances recreational exposure subsample (n=14) .....	59
Table 10. Number of recreational AED-only (n=18) and AED and other substance subsample (n=14) according to symptom status .....	62
Table 11. Number of people presenting to the emergency department reporting illicit drug use in addition to AED use .....	66
Table 12. Summary of cases removed from analysis .....	78
Table 13. Descriptive statistics for demographic variables.....	79
Table 14. Current employment status of participants .....	82
Table 15. Current education status of participants .....	83
Table 16. Descriptive statistics for all alcohol users .....	84
Table 17. Descriptive statistics for all unmixed ED users .....	86
Table 18. Descriptive statistics for all AED Users.....	88
Table 19. Prevalence of alcohol, ED and AED consumption between age groups in the past 12 months.....	89
Table 20. Odds ratios of demographic sub-groups more likely to consume 3 AEDs per session <sup>#</sup> .....	90
Table 21. Key consumption and demographic variables according to resident location .....	91
Table 22. Self-rated change in substance use behaviour due to AED consumption.....	101
Table 23. AED Users: Self-reported reasons for not consuming AEDs within past 12 months .....	113
Table 24. Summary of cases removed from analysis .....	121
Table 25. Descriptive statistics for demographic variables.....	123
Table 26. Descriptive statistics for all alcohol users .....	124
Table 27. Descriptive statistics for all ED users.....	126
Table 28. Descriptive statistics for all AED users .....	128
Table 29. Prevalence of alcohol, ED and AED consumption between age groups: Past 12 months. 129	
Table 30. Key consumption and demographic variables according to street interview location .....	131
Table 31. POINTED participant sex and age by city/interview site .....	139
Table 32. Energy drink consumption by age and gender .....	140
Table 33. Energy drink use and experience of harm in past three months .....	143
Table 34. Protocol for experimental sessions .....	155
Table 35. Demographic characteristics of the sample according to alcohol treatment group (standard deviation in parentheses).....	158
Table 36. Self-reported alcohol, caffeine and energy drink consumption patterns of the sample according to alcohol treatment group (standard deviation in parentheses).....	159

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## LIST OF FIGURES

Figure 1. Annual number of NSWPIC calls according to exposure type (n=39).....	56
Figure 2. Number of NSWPIC calls according to time of day (n=39) .....	57
Figure 3. Number of consumers in the whole sample who reported experiencing symptoms caused by AED consumption or of an unknown relationship to AED consumption (n=31) .....	60
Figure 4. Handling of NSWPIC calls for the whole sample based on the clinical significance of symptoms (n=39) .....	61
Figure 5. Number of AED-only (n=17) and AED and other substances (n=11) recreational consumers only who reported symptoms related to their AED use or of an unknown relationship to AED consumption.....	62
Figure 6. Handling of NSWPIC calls for AED-only recreational consumers (n=18) and AED and other substances recreational consumers (n=14) .....	63
Figure 7. Number of emergency department presentations mentioning recent alcohol and energy drink consumption, by year and sex .....	65
Figure 8. Number of emergency department presentations mentioning recent alcohol and energy drink consumption, by age .....	65
Figure 9. Number of emergency department presentations mentioning recent alcohol and energy drink consumption, by year and admission status .....	67
Figure 10. Number of people presenting symptoms relating to alcohol and energy drink consumption .....	68
Figure 11. Sample distribution of age (% per year) .....	80
Figure 12. Location of top 50 most frequently reported postcodes .....	81
Figure 13. Sample ARIA classification (%) .....	82
Figure 14. Audit-C frequency of alcohol use in past 12 months .....	83
Figure 15. Frequency of high risk alcohol use - 6 or more drinks on one occasion .....	84
Figure 16. ED users - Frequency of ED use in past 12 months .....	85
Figure 17. ED Users - Frequency of high risk ED use: 3 or more drinks on one occasion .....	86
Figure 18. AED users - Frequency of AED use in past 12 months.....	87
Figure 19. Frequency of PMIXAED use in past 12 months .....	93
Figure 20. AED consumption methods reported by AED Users: Frequency (% of AED users).....	94
Figure 21. ALCOHOL ONLY USERS: Frequency of alcohol use in consumption scenarios (%) .....	95
Figure 22. ED USERS: Frequency of ED use in consumption scenarios (%) .....	96
Figure 23. AED USERS: Frequency of AED use in consumption scenarios (%) .....	97
Figure 24. Awareness of current daily energy ED guidelines: percentage of correct response according to age and consumer status (%) .....	98
Figure 25. Between groups illicit substance use – Frequency of illicit substance use during alcohol only sessions by ALCOHOL ONLY users vs. AED users (%) .....	99
Figure 26. Within group illicit substance use – Frequency of illicit substance use during ALCOHOL ONLY sessions vs. AED sessions ( % AED users only).....	100
Figure 27. Motivations for AED use - AED users (% Frequency of motivation) .....	102
Figure 28. Frequency (%) of immediate side effects experienced by ALCOHOL ONLY users.....	104
Figure 29. Frequency (%) of side effects experienced in the days following alcohol use by ALCOHOL ONLY users.....	105
Figure 30. Frequency (%) of immediate side effects experienced by ED users .....	106
Figure 31. Frequency (%) of side effects experienced in days following ED use .....	107
Figure 32. Frequency (%) of immediate side effects experienced during AED use .....	108
Figure 33. Side effects experienced immediately after AED consumption, aggregated according to typical number of EDs during AED session (%).....	109
Figure 34. Frequency (%) of side effects experienced in days following AED use .....	110
Figure 35. Side effects experienced in days following AED use, aggregated according to typical number of EDs during AED session (%).....	111
Figure 36. Between groups analysis: Involvement in physical, verbal or sexual aggression in the past 12 months – ALCOHOL ONLY users vs. AED users (%).....	114
Figure 37. Between groups analysis: Other persons involved in most recent aggressive incident- ALCOHOL ONLY users vs. AED users (%).....	115
Figure 38. Between groups risk taking behaviour – Frequency (%) of risky behaviour during alcohol only sessions by ALCOHOL ONLY users vs. AED users .....	115
Figure 39. Within group risk taking behaviour– Frequency (%) of risky behaviour during ALCOHOL ONLY sessions vs. AED sessions by AED users .....	116

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Figure 40. Prevalence of risk behaviours: aggregated data presenting average energy drink consumption during typical AED sessions in past 12 months (%).....	117
Figure 41. Sample distribution of age (%).....	122
Figure 42. Audit-C frequency of alcohol use in past 12 months .....	123
Figure 43. Frequency of high risk alcohol use - 6 or more drinks on one occasion .....	124
Figure 44. Hourly breakdown of BAC levels for all alcohol users .....	125
Figure 45. ED Users – Frequency of ED use in past 12 months .....	125
Figure 46. Hourly breakdown of ED use for all ED users .....	126
Figure 47. AED Users frequency of AED USE in past 12 months.....	127
Figure 48. Hourly breakdown of AED consumption in current session for AED users .....	130
Figure 49. Motivations for AED use .....	133
Figure 50. Frequency (%) of side effects experienced by ALCOHOL ONLY users .....	134
Figure 51. Frequency (%) of side effects experienced by ED users .....	135
Figure 52. Frequency (%) of side effects experienced during AED use by AED users.....	135
Figure 53. Non-AED Users: Self-reported reasons for not consuming AEDs within past 12 months	136
Figure 54. Between groups analysis: Involvement in physical, verbal or sexual aggression in the past 12 months – ALCOHOL ONLY users vs. AED users (%) .....	137
Figure 55. Age distribution of NSW POINTED interviewees .....	139
Figure 56. Mean energy drinks consumed by hour of day.....	141
Figure 57. Percentage of interviewees consuming AEDs by hour of day.....	141
Figure 58. Main reported motivations for mixing energy drinks and alcohol (N=262) .....	142
Figure 59. Typical frequency of alcohol use in the preceding 12 months according to alcohol treatment group .....	159
Figure 60. Typical frequency of ED use in the preceding month according to alcohol treatment group .....	160
Figure 61. Mean BAC at each time point for the moderate (lower panel) and high (upper panel) alcohol dose groups according to the number of EDs co-ingested (error bars depict the standard deviation).....	162
Figure 62. Mean change in rating of intoxication (0-100) from baseline to 30 minutes after commencing beverage consumption for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation) .....	164
Figure 63. Mean perceived intake of alcoholic drinks (375mL 4.8% beers or 1.4 standard drinks) reported by alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation).....	165
Figure 64. Mean perceived intake of standard 250mL EDs reported by each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation) .....	167
Figure 65. Mean OSPAT score for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation) .....	169
Figure 66. Mean simple reaction time for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation) .....	170
Figure 67. Mean choice reaction time for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation) .....	171
Figure 68. Mean Rapid Visual Processing Latency for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation) .....	172
Figure 69. Mean stop-signal task reaction time for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation) .....	173
Figure 70. Mean number of pegs placed with the dominant hand by each alcohol group according to the number of EDs co-ingested .....	174
Figure 71. Mean number of pegs placed with the dominant hand by males (upper panel) and females (lower panels) in each alcohol group according to the number of energy drinks (EDs) co-ingested .	175
Figure 72. Mean number of pegs completed during the assembly trial by each alcohol group according to the number of EDs co-ingested.....	176
Figure 73. Mean sway area (cm <sup>2</sup> ) for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation) .....	178
Figure 74. Mean time out of lane (%) for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation) .....	179
Figure 75. Mean diastolic blood pressure 30 minutes after commencing beverage consumption for the placebo (top panel), moderate (middle panel) and high (bottom panel) alcohol group according to the number of EDs co-ingested.....	182

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Figure 76. Mean systolic blood pressure 30 minutes after commencing beverage consumption for the placebo (top panel), moderate (middle panel) and high (bottom panel) alcohol group according to the number of EDs co-ingested..... 184

Figure 77. Mean heart rate in beats per minute (bpm) 30 minutes after commencing beverage consumption for the placebo (top panel), moderate (middle panel) and high (bottom panel) alcohol group according to the number of EDs co-ingested ..... 186

Figure 78. Mean time spent speeding (%) by each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation) ..... 189

## ACRONYMS/ABBREVIATIONS

AAMI	Association for the Advancement of Medical Instrumentation
AUDIT	Alcohol Use Disorders Identification Test
AED	Alcohol and Energy Drink
ANZFA	Australia New Zealand Food Authority
BAC	Blood Alcohol Concentration
BP	Blood pressure
BRS	Beverage Rating Scale
CANTAB	Cambridge Neuropsychological Test Automated Battery
CEDUQ	Caffeine and Energy Drink Use Questionnaire
ED	Energy Drink
DU	Deakin University
HEAG	Human Ethics Advisory Group
HREC	Human Research Ethics Committee
HR	Heart Rate
K10	Kessler Psychological Distress Scale
NTE	Night-Time Economy
NDARC	National Drug and Alcohol Research Centre
NHMRC	National Health and Medical Research Council
NSWPIC	New South Wales Poisons Information Centre
OSPAT	Occupation Safety Performance Assessment Task
PMIXAED	Pre-Mixed Alcoholic Energy Drinks
POINTED	Patron Offending and Intoxication in Night-Time Entertainment Districts
PPT	Purdue Pegboard Task
RSA	Responsible Service of Alcohol
RT	Reaction Time
RTI	Reaction Time Index
RVP	Rapid Visual Processing
SES	Subjective Effects Scale
SST	Stop-Signal Task
UTAS	University of Tasmania
US	United States of America
UWS	University of Western Sydney
WTAR	Wechsler Test of Adult Reading

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## DEFINITION OF KEY TERMS

**Accidental paediatric exposure:** non-deliberate ingestion of alcohol and energy drinks by a person under 18 years of age.

**Alcohol and energy drinks:** the combined consumption of alcohol and energy drinks within the one beverage (either hand-mixed or pre-mixed), or as separate drinks within a drinking session.

**Blood Alcohol Concentration:** the concentration of alcohol in the blood, expressed as the weight of alcohol in a fixed volume of blood and used as a measure of the degree of intoxication of an individual.

**Deliberate self-poisoning exposure:** intentional ingestion of alcohol and energy drinks as part of a polypharmacy overdose.

**Emergency Department:** a medical treatment facility specialising in acute care of patients.

**Energy drink:** a functional beverage promoted as increasing alertness and endurance, commonly containing caffeine, taurine, and glucuronolactone, amongst other ingredients.

**New South Wales Poisons Information Centre:** a poisons centre based in New South Wales which provides information regarding risk assessment, management and treatment of human poisoning for the general public and health care professionals.

**Recreational exposure:** intentional ingestion of AED for the purpose of gaining euphoria or other psychotropic effects.

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## CONTENTS

<b>EXECUTIVE SUMMARY .....</b>	<b>1</b>
<b>Introduction .....</b>	<b>1</b>
<b>Methods.....</b>	<b>2</b>
<b>Results .....</b>	<b>2</b>
<b>Discussion and Recommendations .....</b>	<b>10</b>
<b>1. INTRODUCTION.....</b>	<b>14</b>
<b>2. LITERATURE REVIEW .....</b>	<b>16</b>
<b>2.1 Aims and Method .....</b>	<b>16</b>
<b>2.2 Energy Drinks.....</b>	<b>16</b>
2.2.1 Caffeine .....	17
2.2.2 Taurine .....	18
2.2.3 Sugars .....	18
2.2.4 Glucuronolactone .....	19
<b>2.3 Prevalence of ED Use .....</b>	<b>19</b>
<b>2.4 Effects of ED Consumption .....</b>	<b>21</b>
2.4.1 Performance Outcomes .....	21
2.4.2 Subjective Psychological and Physiological Outcomes of ED Use.....	25
2.4.3 Behavioural Risk-Taking Outcomes of ED Use .....	29
<b>2.5 Alcohol and EDs.....</b>	<b>30</b>
<b>2.6 AED Prevalence.....</b>	<b>30</b>
2.6.1 International Studies.....	30
2.6.2 Australian Studies.....	31
<b>2.7 AED Consumption Patterns .....</b>	<b>33</b>
2.7.1 International Studies.....	33
2.7.2 Australian Studies.....	34
<b>2.8 Socio-demographics and Characteristics of AED Users .....</b>	<b>35</b>
2.8.1 International Studies.....	35
2.8.2 Australian Studies.....	35
2.8.3 Substance Use and Risk-Taking Characteristics – International Studies .....	35
<b>2.9 Motivations to Consume AEDs.....</b>	<b>37</b>
2.9.1 International Studies.....	37
2.9.2 Australian Studies.....	37
2.9.3 Do AEDs Reduce Impairment and Increase Alertness? .....	38
2.9.4 Do AEDs Facilitate Increased Alcohol Intake?.....	41
<b>2.10 Side-effects of AED Use .....</b>	<b>43</b>
2.10.1 Physiological and Psychological Side-effects of AEDs .....	43
2.10.2 Do AEDs Increase Risk-Taking?.....	47
<b>2.11 Current International ED and AED Policy.....</b>	<b>48</b>
<b>2.12 Current National ED and AED Policy .....</b>	<b>49</b>

---

<b>2.13 What Future Research is Needed?</b> .....	<b>51</b>
<b>3. ANALYSIS OF SECONDARY DATA</b> .....	<b>54</b>
<b>3.1 Introduction and Aims</b> .....	<b>54</b>
<b>3.2 Poisons Data</b> .....	<b>54</b>
3.2.1 <i>Methods</i> .....	54
3.2.2 <i>Results</i> .....	56
3.2.2.1 <i>General Overview of PIC Calls</i> .....	56
3.2.2.2 <i>Demographics and Exposure Characteristics</i> .....	58
3.2.2.3 <i>Side-Effects of Exposure</i> .....	60
<b>3.3 Emergency Department Data</b> .....	<b>63</b>
3.3.1 <i>Methods</i> .....	63
3.3.2 <i>Results</i> .....	64
<b>3.4 Discussion</b> .....	<b>68</b>
3.4.1 <i>Limitations</i> .....	70
3.4.2 <i>Recommendations for future data collection</i> .....	70
<b>4. SURVEY FINDINGS</b> .....	<b>74</b>
<b>4.1 Introduction</b> .....	<b>74</b>
<b>4.2 Aims</b> .....	<b>75</b>
<b>4.3 Web Survey</b> .....	<b>75</b>
4.3.1 <i>Methods</i> .....	75
4.3.1.1 <i>Measures</i> .....	75
4.3.1.2 <i>Recruitment Strategies</i> .....	75
4.3.1.3 <i>Sample Size</i> .....	76
4.3.1.4 <i>Survey Procedure/Administration</i> .....	76
4.3.1.5 <i>Data Analysis</i> .....	77
4.3.2 <i>Results</i> .....	77
4.3.2.1 <i>Description of the Sample</i> .....	77
4.3.2.2 <i>Substance Use</i> .....	83
4.3.2.3 <i>Alcohol Use</i> .....	83
4.3.2.4 <i>Energy Drink Use</i> .....	85
4.3.2.5 <i>Alcohol and Energy Drink Use</i> .....	87
4.3.2.6 <i>Between Groups Comparisons: Alcohol Only versus AED Consumers</i> .....	92
4.3.2.7 <i>Within Groups Comparisons: AED Consumers</i> .....	92
4.3.2.7 <i>Premixed AED Use</i> .....	93
4.3.2.8 <i>AED Users: Self Reported AED Consumption Methods</i> .....	93
4.3.2.9 <i>Consumption Scenarios: Comparison of Alcohol, ED and AED users</i> .....	94
4.3.2.10 <i>Knowledge of Guidelines around Maximum Daily Consumption of EDs</i> .....	98
4.3.2.11 <i>Illicit Substance Use</i> .....	99
4.3.2.12 <i>Motivations for Alcohol and AED Use</i> .....	101
4.3.2.13 <i>Experience of Side Effects: Comparison of Alcohol, Energy Drink and AED users</i> .....	103
4.3.2.14 <i>Involvement in Risk Taking Behaviours and Aggression</i> .....	114
<b>4.4 Street Survey</b> .....	<b>118</b>
4.4.1 <i>Methods</i> .....	118
4.4.1.1 <i>Measures</i> .....	118
4.4.1.2 <i>Sample</i> .....	118
4.4.1.3 <i>Setting</i> .....	118
4.4.1.4 <i>Survey Procedure</i> .....	119
4.4.1.5 <i>Data Analysis</i> .....	120
4.4.1.6 <i>Ethics</i> .....	121
4.4.2 <i>Results</i> .....	121

---

4.4.2.1 Description of the Sample .....	121
4.4.2.2 Alcohol Use .....	123
4.4.2.3 Energy Drink Use .....	125
4.4.2.4 Alcohol and Energy Drink Use .....	127
4.4.2.5 Between Groups Comparisons: Alcohol Only versus AED Consumers .....	132
4.4.2.6 Within Groups Comparisons: AED Consumers .....	132
4.4.2.7 Motivations for AED Use .....	133
4.4.2.8 Experience of Side Effects: Comparison of Alcohol, Energy Drink and AED users .....	134
4.4.2.9 Reasons for Avoiding Consumption of AEDs.....	136
4.4.2.10 Involvement in Risk Taking Behaviours and Aggression .....	137
<b>4.5 Comparison with Existing Data – The POINTED Project .....</b>	<b>138</b>
4.5.1 Introduction to POINTED.....	138
4.5.1.1 Sydney.....	138
4.5.1.2 Wollongong.....	138
4.5.2 Results.....	139
4.5.2.1 Sample Characteristics .....	139
4.5.2.2 Energy Drink Consumption .....	140
4.5.2.3 Energy drink use and experience of aggression/harm.....	142
4.5.2.4 Energy drink use and offending behaviour.....	143
<b>4.6 Discussion .....</b>	<b>143</b>
4.6.1 Limitations .....	145
4.6.2 Key Findings and Recommendations.....	146
<b>5. EXPERIMENTAL FINDINGS .....</b>	<b>148</b>
<b>5.1 Introduction .....</b>	<b>148</b>
<b>5.2 Objectives .....</b>	<b>149</b>
<b>5.3 Methods .....</b>	<b>150</b>
5.3.1 Participants.....	150
5.3.2 Materials and Apparatus .....	151
5.3.3 Procedure.....	153
5.3.4 Study Restrictions.....	154
5.3.5 Assignment of Treatment Order.....	154
5.3.6 Experimental Sessions.....	154
5.3.7 Administered Treatments .....	155
5.3.8 Analyses.....	156
<b>5.4 Results .....</b>	<b>157</b>
5.4.1 Sample Characteristics.....	157
5.4.2 Blood Alcohol Concentration (BAC) .....	160
5.4.3 Perceived Intoxication .....	163
5.4.4 Objective Intoxication Outcomes.....	168
5.4.5 Physiological Intoxication Outcomes.....	181
5.4.6 Behavioural Risk-Taking Outcomes .....	188
<b>5.5 Discussion .....</b>	<b>190</b>
<b>6. DISCUSSION AND RECOMMENDATIONS .....</b>	<b>201</b>
<b>6.1 Study Limitations .....</b>	<b>211</b>
<b>6.2 Conclusions and Recommendations.....</b>	<b>213</b>
<b>7. REFERENCES.....</b>	<b>218</b>

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## EXECUTIVE SUMMARY

### Introduction

Alcohol-related problems, particularly those associated with the night-time economies of urban and regional centres, are the subject of substantial community concern across Australia. While the number of people drinking in Australia appears to be declining (1), and population levels of consumption appear stable (2), there have been increases over time in alcohol-attributable emergency department presentations in most jurisdictions across Australia, and these increases are independent of an overall increase in presentations over time (3). This is true of NSW, where there has been a significant increase in alcohol-related emergency department presentations among people aged 16-24 in the past fifteen years (4). One explanation for this may be the nature at which young people consume alcohol in the night-time economy, with national data indicating that almost one third of 18-29 year olds consume alcohol above National Health and Medical Research Council thresholds for 'risky drinking' (five or more drinks/day - 5) weekly, and over half do so monthly (1). It is therefore no surprise that alcohol is consistently associated with injury and violence among young people of this age group (6).

There have been concerns that mixing alcohol with energy drinks (AED) may be associated with risky drinking and alcohol related harms (7). Despite a growing body of research indicating that AED use is increasing, Australian research on this issue is lacking and the current evidence base is insufficient to provide clear direction for Governments to take action in relation to health promotion or regulation. In particular, NSW Health identified that there was an evidence gap in terms of understanding how widespread the practice of mixing alcohol and energy drinks is within NSW, what the impacts of AED consumption are on health and behaviour at both the individual and population level, and what dosage of AEDs are associated with adverse health or behavioural effects.

This research addresses the following questions:

1. What is the current Australian and international evidence of the effects of mixing alcohol and energy drinks? What are the gaps in the evidence? What regulations nationally and internationally have been imposed on energy drinks (ED) when intended to be consumed with alcohol?
2. What do routine data collections tell us about the harms from mixing alcohol and energy drinks? What don't they tell us? Can we determine the effects on the health system?
3. How widespread is the practice of mixing alcohol and energy drinks amongst the NSW population?
  - What population groups mix alcohol with energy drinks?
  - What are the characteristics of use (i.e., When and where does it occur? How much is drunk? In what proportions? How often? Why?)
  - What are the health and social harms experienced from mixing alcohol and energy drinks? At what amount of energy drink and what amount of alcohol do these effects occur?
  - Does use differ between metropolitan, regional and rural communities?

4. Does AED use cause an underestimation of perceived intoxication? Does AED use cause an increase or decrease in actual intoxication outcomes via impairment on cognitive and motor performance outcomes? Does AED use increase or decrease heart rate and blood pressure? Does AED use cause an increase in behavioural risk-taking? If present, are these effects dose-dependent?
5. What is the maximum level of caffeine and other energy drink active ingredients in a standard alcoholic drink before adverse health effects occur? At what volume of energy drink and alcoholic drink do these adverse health effects occur?

## Methods

A four phased approach to addressing these questions was determined appropriate, involving: a) a comprehensive review of the international literature; b) quantitative analysis of existing population level data in NSW; c) a web-survey and a night-time street intercept survey with NSW residents; and d) an experimental study to determine the effects of mixing alcohol and energy drinks on physiology, coordination, cognitive performance and risk-taking behaviour.

## Results

**Research Question 1: What is the current Australian and international evidence of the effects of mixing alcohol and energy drinks? What are the gaps in the evidence? What regulations nationally and internationally have been imposed on energy drinks when intended to be consumed with alcohol?**

### *Prevalence and Patterns of AED use and Demographics of Consumers*

- Between 15% and 50% of sub-populations such as university students report having consumed AEDs recently in the US and Europe.
- The only available data in Australia reports that nearly half of a targeted community sample and 70% of regular ecstasy users had used an AED in the past six months, but rates of use are likely to be lower in general population samples.
- Most AED users consume them fortnightly to monthly and drink approximately three AEDs per session; but a smaller group of people consume AEDs more regularly and at higher quantities.
- Most AED users hand-mix EDs with Vodka and Jagermeister® and they are most popular within licensed venues.
- North American AED consumers are more likely to be Caucasian, male and younger (18-30 years), but little is known about the socio-demographic characteristics of Australian AED users.
- International research reports that AED users are more likely to consume alcohol frequently, consume higher quantities of alcohol per session, display a higher propensity for risk-taking and engage in more risk-taking behaviours relative to non-AED users. However, it is unclear

whether this is because people high in risk-taking propensity are attracted to AED consumption and/or whether AED consumption causes increases in risk-taking behaviour.

#### *Motivations for AED use*

- The main benefits of AED use, as reported by consumers, are: a) stimulation, wakefulness and energy; b) appealing taste; c) reduced inebriation and the facilitation of a more desirable drunkenness; and d) the facilitation of intoxication.
- However, international experimental studies show that combining EDs with alcohol does not alter consumers' intoxication levels or improve performance and motor coordination. Experimental research has reported mixed findings in relation to whether AED consumption increases feelings of stimulation and reduces perceptions of fatigue relative to alcohol only, and research is mixed as to whether AED users consume more alcohol during AED sessions or alcohol-only sessions.

#### *Side-effects associated with AED use*

- The primary self-reported side-effects associated with AED consumption include: a) dehydration and a worse hangover (self-reported as worse relative to alcohol-only sessions); b) sleeping difficulties; and c) physiological impairment such as increased heart rate, palpitations, gastrointestinal upset, vomiting and nausea.
- There are mixed findings regarding the relationship between AED consumption and risk-taking, with some research reporting greater engagement in risk-taking during sessions of AED use compared to sessions of alcohol use, and others showing the opposite.

#### *Regulation of AEDs*

- The US has banned the sale of pre-mixed AEDs, and Mexico has prohibited the sale of AEDs in licensed venues. Canada has recently reduced the amount of caffeine in energy drinks (no more than 400mg of caffeine is permitted per litre or 180mg per single serve; it should be noted that this is less strict than Australian regulations), and now requires that energy drinks have the following warning labels: 'do not mix with alcohol', 'high source of caffeine', and 'not recommended for children, pregnant/breastfeeding women, individuals sensitive to caffeine' (this last statement is included on the cans of most energy drinks). There have been few regulatory actions adopted in Europe. The Australia New Zealand Food Standards Code specifies that EDs may contain a maximum of 320mg/L caffeine, or 80mg per 250mL standard ED. Restrictions also exist for the amount of taurine and glucuronolactone permitted in EDs. These restrictions are stricter than those imposed in other countries. The only regulation on the supply of AEDs in Australia is in Perth, Western Australia, where inner-city late-night venues are prohibited from selling AEDs after midnight, but this policy is undermined by the continued sale of EDs in the same venues after midnight.

*The following gaps in the Australian evidence were identified through the literature review:*

- There is no prevalence data collected on AED use in general population samples in Australia;

- There has been limited investigation into the prevalence of AED use among specific AED-using populations such as university students, non-university students aged 18-30, illicit drug users and people under the age of 18 in Australia;
- There is no freely accessible sales data on AED use in Australia;
- There is insufficient qualitative data on the social and cultural contexts of AED use amongst diverse samples including those who consume a moderate number of AEDs per session, and those who consume above the daily recommended number of EDs per AED session;
- Insufficient research has been undertaken among venue staff, police and emergency services personnel in order to understand the role that AED use plays for their service in relation to intoxication, side-effects and/or violence; what their training needs are in relation to treating AED-related harms, and how they currently collect and record information about AED use;
- The link between personality, risk-taking propensity and AED use is still unclear; for example, whether people high in risk-taking propensity are attracted to AED use and/or whether AED use causes increases in risk-taking behaviour;
- It is unclear what the dose-response relationship of AEDs is and at what levels of alcohol and EDs potential side-effects rise appreciably;
- The effects of AED use on objective measures of performance and risk-taking, and subjective measures of intoxication is unclear when AEDs are consumed at doses similar to those consumed in real-life; and
- No evidence exists for the effectiveness of policies implemented to reduce access to AEDs, such as the Western Australian restrictions.

**Research Question 2: What do routine data collections tell us about the harms from mixing alcohol and energy drinks? What don't they tell us? Can we determine the effects on the health system?**

- Information on AED use is not well collected by emergency services as part of routine data collection. The only data we were able to access was calls made to the NSW State-Wide Poisons Information Centre (NSWPIC) and presentations to NSW emergency departments.
- Over a nine year period 39 poison centre calls related to AED use were recorded to NSWPIC, which represented 0.006% of all unique exposure-related calls. Over a six year period, there were 657 presentations related to AED use across 59 emergency departments in NSW, representing 0.00006% of all presentations in the period. These numbers increased around 2007-08 but have remained stable since.
- The number of calls relating to AED use was split evenly by gender in both the poison centre calls and emergency department presentations and the majority involved adolescents and young adults. Specifically, 84% of emergency department presentations involved people aged 15-29, and 32% of those presenting to an emergency department and 18% of NSWPIC calls involved adolescents (aged of 15-19). Over two thirds of poison centre calls involved the co-ingestion of AEDs with other substances, but only one sixth of AED presentations to emergency departments involved the co-ingestion of illicit drugs.

- The primary symptoms reported in the context of both poison centre calls and emergency department presentations included agitation, anxiety, tremors, tachycardia, arrhythmias, chest pain/tightness nausea and vomiting. This is consistent with the literature of self-reported acute side effects of AED use.
- The majority of emergency department presentations did not result in longer-term hospital admission, indicating that AED presentations resolve fairly quickly. However, of the approximate 50 presentations that did result in hospital admission, six of these resulted in admissions to the critical care ward.

*Conclusions about routine data collection of AED use and harms in NSW:*

- There is very little secondary data that can be sourced in NSW to paint a comprehensive picture of the nature of harms from AED use. What data were available reveals that there have been very low numbers of AED-related calls to NSWPIC and NSW emergency departments over the past nine years, suggesting that AED use is not placing a significant burden on acute emergency services. However, these numbers are likely to represent an underestimation of the harms associated with AED use due to poor recording of alcohol and energy drinks in routine data collection systems and appropriate coding of AED use by paramedics will be useful to ensure harms are not going unrecorded.

**Research Question 3: How widespread is the practice of mixing alcohol and energy drinks amongst the NSW population?**

- Over one third (38%) of survey respondents reported AED use in the past 12 months.
- Approximately 10% of people had consumed an AED on the night of the street intercept interview.

**What population groups mix alcohol with energy drinks?**

- Males in NSW were more likely to consume AEDs and consume significantly greater amounts of AEDs than females. Participants aged 18-25 were more likely to consume AEDs than other age groups; however, there was little difference in quantity of AED use by adult age groups. Other demographics associated with increased likelihood of AED use were being single or casually dating (as opposed to being in a steady relationship) and being a tertiary student.
- Although only making up 3.4% of the sample, there was a high rate of AED use reported by 16-17 year olds in the street survey component of the study. Participants of this age group reported 5.36 EDs per AED session, which was almost 2 EDs more than older age groups. In addition, 16-17 year olds in the street survey reported the highest amount of alcohol in a typical AED session (10.6 drinks). When considering this finding it is important to bear in mind that 16-17 year olds comprised a very small portion of the street sample and people of this age group who are on the street late at night are likely to be a 'riskier' demographic of young people; however, more research on AED use is needed among young people to contextualise this finding, particularly given that analysis of secondary data reported that 32% of those

presenting to an emergency department and 18% of NSWPIC calls relating to AED use involved adolescents.

**What are the characteristics of use (i.e., When and where does it occur? How much is drunk? In what proportions? How often? Why?)**

- AED consumers recruited through the web-survey reported consuming AEDs monthly or less, while approximately half of AED consumers recruited through the street intercept survey consumed them at least monthly.
- Web-survey participants reported consuming on average 6.0 alcoholic drinks and 3.0 EDs per AED session. Street intercept survey participants reported consuming on average 8.4 alcoholic drinks and 3.6 EDs per AED session.
- Findings from the street intercept survey revealed that by 10pm the average AED user had exceeded the recommended daily intake of energy drinks (which is two per day). By 2am, AED users had consumed an average of 3.6 standard energy drinks.
- The majority (85.2%) of web-survey participants preferred to hand-mix their AEDs, as opposed to consuming pre-mixed AEDs.
- Participants reported using AEDs most commonly within licensed venues, at private parties and at music festivals.
- The most frequently reported motivations for AED use were energy/endurance, compensating for lack of sleep and taste. Price and availability were also strong motivations.

**What are the health and social harms experienced from mixing alcohol and energy drinks? At what amount of energy drink and what amount of alcohol do these effects occur?**

- The most commonly reported side effects experienced by AED users *during* sessions of AED use were racing heart/heart palpitations, insomnia, energy fluctuations and nausea. These side effects increased with increasing AED dose, and were most commonly reported after five AEDs. Racing heart was consistently the most commonly reported side effect at all levels of consumption, increasing from 43% after 1 AED to 70% after 5 AEDs. However, at higher levels of consumption other side effects such as slurred speech, increased rate of speech, dizziness and decreased coordination became more common. These symptoms are consistent with the findings from the secondary analysis of NSWPIC and emergency department data.
- The most commonly reported '*after*' effects (in the days following) of AED use were visual disturbances, nausea and fatigue. These side effects increased with increasing AED dose, and were most commonly reported after the consumption between 4-6 AEDs. Visual disturbances were the most commonly reported '*after*' effect of AED use at all levels of consumption, but at five AEDs and above side-effects such as nausea and fatigue were replaced with side-effects such as breathing difficulties, gastrointestinal issues, racing heart and heart palpitations. These symptoms are consistent with the findings from the secondary analysis of NSWPIC and emergency department data.

- People who had consumed AEDs in the past 12 months consumed significantly more alcohol than people who had not used AEDs (but had consumed alcohol) in the past 12 months. AED users also consumed more illicit substances in the past 12 months than non-AED users, and AED users reported a higher proportion of involvement in aggressive incidents in the past 12 months than non-AED users.
- However, within groups analyses revealed that AED consumers consumed more alcohol during typical 'alcohol only' sessions than during typical AED sessions (6.7 versus 6.0 drinks), and they consumed illicit drugs more frequently during 'alcohol only' sessions than during AED sessions.
- Among AED users, those who reported consuming greater than two AEDs in a typical AED session reported a significantly higher number of risk taking behaviours than those who consumed two or less AEDs (5.8 risk-taking events versus 3.2).

#### **Does use differ between metropolitan, regional and rural communities?**

- The web-survey findings revealed that Sydney residents were less likely to consume AEDs than residents in Newcastle and other areas. However, when talking to those on the street, rates of AED use were consistent across nightlife locations in Sydney, Newcastle and Orange. This suggests that a larger percentage of young people living in regional areas may consume AEDs, but there are similar rates of AED use in the night-time economy across geographic locations in NSW.
- Over 99% of the web-survey sample lived in areas deemed accessible or highly accessible according to ARIA classifications (Accessibility/Remoteness Index of Australia - 8), meaning the sample living in rural or remote communities was too small to assess differences in AED use.

#### **Research Question 4: Does AED use cause an underestimation of perceived intoxication? If present, are these effects dose-dependent?**

- In the experimental study participants had a lower blood alcohol concentration (BAC) when combining alcohol (moderate dose ~ .050% BAC or high dose ~.080% BAC) and EDs relative to consuming alcohol alone, particularly when ingesting quantities of ED which matched or exceeded the recommended daily intake (i.e., two or three standard EDs). BAC tended to decrease dose-dependently according to the volume of ED ingestion. However, this effect was only apparent after consuming a moderate alcohol dose. Previous research has shown that consumption of naturally sweetened alcohol mixers results in lower BACs than artificially sweetened beverages, as the latter are treated almost like a food by the body and cause a slower gastric emptying and slower alcohol absorption. Thus, the higher BACs evident in the present study after consumption of the active naturally sweetened ED beverages relative to the artificially sweetened placebo beverage may reflect this slower rate of gastric emptying and absorption. These results, considered in conjunction with past research, suggest that lower BAC may not be specific to EDs and may be apparent for all naturally sweetened

alcohol mixers. Further research is required to confirm the specific role of sugar in changes in BAC following ED consumption and confirm that comparable changes are evident when people ingest other naturally sweetened mixers. These results should also be interpreted in light of the following outcomes (see below) which indicate that AEDs generally do not alter perception of intoxication or performance outcomes after controlling for differences in BAC.

- Consumption of the high ED dose (i.e., three standard EDs) lowered perception of intoxication relative to when no ED was consumed, or when a low or moderate ED dose was consumed (i.e., one or two standard EDs); this effect occurred regardless of actual alcohol intake. However, this outcome may have reflected an accurate estimation of intoxication by participants, as BAC was typically lower after consumption of a higher ED doses relative to no ED consumption. This conclusion is supported by analyses taking into account these differences in BAC, revealing that there was no significant difference in perceived intoxication when participants consumed alcohol relative to AED. The results of this study do not support premise that AED alters perception of intoxication relative to consuming alcohol alone.
- Further support for this conclusion was evident in participants' perception of alcohol consumed, as participants' ratings of perceived alcohol intake did not differ when alcohol was consumed with or without ED, regardless of the volume of ED consumed.
- Participants were generally poor at detecting their ED intake when consuming the moderate and high alcohol dose, particularly when ED consumption exceeded the recommended daily maximum intake. These results suggest that consumers in the night-time economy may have a reduced ability to detect and monitor their ED intake if there is no visible indication of the servings consumed.

#### **Does AED use cause an increase or decrease in actual intoxication outcomes via impairment on cognitive and motor performance outcomes? If present, are these effects dose-dependent?**

- The present results showed that consuming alcohol with EDs generally did not change cognitive performance relative to when alcohol was consumed without EDs. However, these results need to be treated with caution as analyses revealed low statistical power to detect treatment effects for several cognitive measures.
- There were some alterations in motor performance following AED consumption; balance was improved when the moderate alcohol dose was consumed with three EDs relative to no EDs and female participants showed better gross motor movement when they consumed the moderate or high alcohol dose without any EDs compared to having two or three standard EDs. There were no changes in fine motor movement.
- These results suggest that mixing alcohol and EDs does not alter cognitive performance and generally does not impact motor performance relative to when alcohol is consumed alone. Participants did display some improvement of balance after consuming a moderate alcohol dose with a high ED dose, however it cannot be inferred whether this would translate practically into a decreased risk of falls or injury.

### **Does AED use increase or decrease heart rate and blood pressure? If present, are these effects dose-dependent?**

- The results of the present study showed that consuming alcohol with a high ED dose which exceeded the recommended intake (i.e., three standard EDs) decreased diastolic blood pressure (BP) compared to when alcohol was consumed without EDs. This effect only occurred when the moderate alcohol dose was consumed.
- There was no difference in systolic BP according to the amount of alcohol or ED consumed, and whether they were consumed together.
- In regards to heart rate (HR), the results showed that the decrease in HR seen when the moderate dose of alcohol was consumed alone or with a low ED dose tended to disappear when consuming alcohol with an ED dose equivalent to, or in excess of, the recommended daily intake guidelines. The same results were evident following the high alcohol dose, except the high ED dose (i.e., three standard EDs) increased HR relative to low or no ED consumption.
- Overall, it appears that mixing alcohol with EDs does alter blood pressure and heart rate relative to consuming alcohol without EDs, however these effects are dependent on the amount of alcohol and ED consumed together. A moderate alcohol dose consumed with a high ED dose decreased diastolic blood pressure and a high alcohol dose consumed with a high ED dose increased HR, compared to when consuming alcohol without EDs. However these results should be interpreted with caution, as these changes do not necessarily translate into clinically significant and meaningful risk for AED consumers. We cannot infer from these results that consumers are at an increased risk of short or long-term cardiovascular harms.

### **Does AED use cause an increase in behavioural risk-taking? If present, are these effects dose-dependent?**

- Driving risk-taking was not dose-dependently impacted by alcohol, ED, or AED consumption. While these results suggest that alcohol mixed with EDs does not impact risk-taking relative to when alcohol is consumed alone, the outcomes should be interpreted in the context of a very low overall rate of risk-taking by all participants, regardless of alcohol or ED dose, and the fact that there was only one measure of risk-taking. These results could reflect compensatory responding by participants for perceived intoxication, particularly as task reimbursement was dependent on the number of road rules broken, as well as the time taken to complete the drive.

### **Research Question 5: What is the maximum level of caffeine and other energy drink active ingredients in a standard alcoholic drink before adverse health effects occur? At what volume of energy drink and alcoholic drink do these adverse health effects occur?**

- The experimental study found that heart rate increased when three EDs were consumed with the high alcohol dose and diastolic blood pressure decreased when three EDs were

consumed with the moderate alcohol dose. These findings suggest that mixing alcohol with EDs does alter physiological outcomes after three EDs. However, whether these changes translate into clinically significant and meaningful risk for AED consumers is not clear as we cannot infer from these results that consumers are at an increased risk of short or long-term cardiovascular harms.

- Survey findings demonstrated that some participants reported side-effects after 1 AED suggesting there is no definitive number of AEDs that can be consumed before health effects occur. However, side effects experienced during sessions of AEDs were reported by participants to be more common after 5 AEDs and side effects experienced in the days(s) following AED use were reported to be more common after 4-6 AEDs.
- Among AED users, self-reported involvement in risk-taking behaviours increased as the dose of energy drink use increased, with participants who consumed between 4-5 energy drinks reporting the most risk-taking behaviours.
- Given that ethical constraints prohibited us from administering participants' more than three energy drinks and 0.65g/kg of alcohol, this might explain the absence of findings in relation to increased risk-taking, cognitive impairment and poorer motor performance in the experimental study.

## Discussion and Recommendations

The current study filled many of the research gaps that we identified in the literature review, particularly in relation to a) understanding the popularity of AED use among the population of interest (i.e., young NSW residents most likely to frequent the night-time economy), as well as patterns of use, quantity and frequencies of use, socio-demographics of users, use across geographical locations, benefits and side-effects of use; b) a preliminary understanding of the burden that AED use plays for emergency services; c) a better understanding that AED consumption does not necessarily cause increases in risk-taking behaviour, but that AED users are a riskier group of consumers for whom targeted intervention is warranted; d) an indication that AED side-effects and risk-taking behaviours are most commonly reported after the consumption of between 4-6 AEDs, and e) knowledge that AED consumption of up to three EDs and 0.65g/kg of alcohol does not result in significant physiological impairment or influence cognitive and motor performance and risk-taking. However, the findings from our study also raise some additional questions, such as why does combining alcohol and EDs lead to reports of visual disturbances in the days following use?

We propose a number of recommendations in relation to health promotion, legislation, data monitoring and future research given that we found: i) high levels of AED use among adolescents, ii) the majority of AED users reported experiencing negative side-effects during and after consumption, iii) most AED consumers were exceeding recommended guidelines in relation to the maximum number of energy drinks that should be consumed daily, and iv) AED consumers are a group of people who engage in heavier alcohol and drug consumption and risk-taking behaviours than non-AED consumers.

## Health promotion

Although experimental findings did not show significant adverse outcomes from alcohol and energy drinks at doses of up to 0.08% BAC and 3 energy drinks, survey findings revealed that AED users were consuming higher levels of alcohol and energy drinks than this and experienced side effects such as increased heart rate and heart palpitations during sessions of use, and visual disturbances and nausea in the days following AED consumption. Survey findings also revealed that experience of side-effects increased with increasing AED dose and that knowledge of side effects predicted reduced use of AEDs. As such, we recommend a range of activities to raise awareness of the potential side effects of AED use. These include:

- Media campaigns raising awareness about the harms of excessive alcohol consumption and the potential for energy drinks to contribute to this, targeted at the demographic of consumers using AEDs frequently at high levels – people aged 18-25 years, particularly young males and tertiary students. This might include television advertisements, billboards or other forms of media. A cost effective way of doing this would be to add energy drink information to an existing alcohol campaign rather than running a separate campaign;
- Given that AEDs are most commonly consumed in licensed venues, this is an ideal location for targeted advertising. We recommend that posters be distributed to venues for placement in key locations such as toilets, containing information about the potential risks associated with combining alcohol and energy drinks;
- Use of AEDs was also high among 16-17 year olds indicating that prevention and health promotion messages in schools is warranted. Adding an AED component to existing drug education programs offered in schools might be an effective way of disseminating messages around potential harms of use.
- Information should be included on the packaging of EDs that allow consumers to purchase over the recommended daily intake (e.g., 1.25L bottles, 4 packs/6packs, etc.) warning of the 'high caffeine content' (similar to European and Canadian requirements).

## Legislation

Survey data revealed that price was a motivating factor for AED consumption and that consumption of more than two EDs significantly increased the likelihood of risk-taking behaviour. Furthermore, experimental data showed that consumers are not good at detecting their ED intake, particularly when consuming in excess of the current recommended maximum daily intake. As such, we recommend:

- Guidelines should be put in place to ensure the advertising, promotion or discounting of AEDs must have reasonable limits and controls to minimise the risk of rapid, excessive or irresponsible consumption of AEDs;
- Guidelines should be put in place to ensure that advertisements or promotions of AEDs should not involve the availability of non-standard sized drinks or the availability of AEDs in receptacles that encourage rapid drinking.

## Data Monitoring

Due to the limited Australian information available on AED use identified through the literature review and our scoping of data across health and administrative systems in NSW, we recommend:

- Questions relating to AED should be added to existing general population surveys (such as the National Drug Strategy Household Survey) so that trends can be monitored (relatively inexpensively) over time;
- Questions relating to AED should be added to existing surveys accessing high risk subpopulations such as youth (such as the Australian School Students Alcohol and Drug Survey) and illicit drug users (such as the Ecstasy and Related Drugs Reporting System and the Illicit Drugs Reporting System) so trends can be monitored over time;
- Enhancement of additional coding of ambulance attendance data should be undertaken to enable identification of serious AED-related harms that occur without requiring transportation to hospital;
- Annual review of emergency department presentations data should be undertaken (utilising search terms for case notes) to monitor trends in presentations over time; and
- Annual monitoring of calls to the NSW Poisons Information Centre should be undertaken to identify trends in relation to AED harms over time.

## Research

While this study has filled some important gaps in our knowledge around the use of AEDs, particularly in NSW, there are still a number of avenues for investigation:

- We deliberately targeted the likely demographic of AED users in our sampling and it will be useful to also ascertain the prevalence of AED use in general population samples (including patterns of use, quantity and frequencies of use, socio-demographics of users, benefits and side-effects);
- Targeted research directed at specific sub-populations that were not significantly represented in this research and showed high levels of AED use, such as illicit drug users and *especially people under the age of 18*, will be useful to understand how different groups of people are using AEDs (including patterns of use, quantity and frequencies of use, socio-demographics of users, benefits and side effects);
- It would be useful to access sales data on EDs and pre-mixed AEDs to provide insight as to their popularity and consumption patterns across Australia;
- There have only been two small qualitative studies conducted in Australia with AED users, and as such there has been insufficient research exploring patterns of use and the social and cultural contexts of AED use amongst diverse samples including those who consume a moderate number of AEDs per session, and those who consume above the daily recommended number of EDs per session;

- Quantitative, qualitative and experimental research is needed to explore our finding in relation to visual disturbances, such as whether these effects are unique to AED use, the nature and severity of the visual disturbances, how they might impact driving and similar tasks and whether they occur after particular doses of AEDs.
- There has yet to be sufficient research conducted with venue staff, police and emergency services personnel, including observational research, interviews and analysis of ambulance and police data in order to understand a) the role that AED use plays for their service in relation to intoxication, side-effects and/or violence, b) what they know about AED-related harms and whether they need more training in treating AED-related harms; and c) how they currently collect and record information about AED use and whether there are more appropriate recording systems that can be implemented to more accurately gather information about AED use;
- Policy evaluation research is needed, such as research examining the impact of the Western Australian prohibition of sales of AEDs after midnight in inner-city venues;
- The results of the experimental research demonstrated that BAC tended to decrease with an increasing ED dose; however, this may be a consequence of higher sugar content in the active ED condition slowing the rate of alcohol absorption via longer gastric emptying. Further research is required to determine the independent effects of the primary ED ingredients on alcohol metabolism; and
- Participants in the experimental study were informed that they may receive a maximum of six alcoholic drinks per session which may explain low levels of behavioural risk-taking. Future research should examine the effects of alcohol expectancy, looking specifically at the impact of explicitly informing participants of the treatment administered. Such research would increase the ecological validity of outcomes, as it would be rare that AED consumers would be blind and unaware of the content of the beverage they were consuming.

## 1. INTRODUCTION

Alcohol-related problems, particularly those associated with the night-time economies of urban and regional centres, are the subject of substantial community concern within Australia. A recent Turning Point report identified that almost 75% of adult Australians have been negatively affected by someone else's drinking, with more than 70,000 Australians victims of alcohol-related assaults every year (9). While the number of people drinking in Australia appears to be declining (1), and population levels of consumption appear stable (2), there have been increases over time in alcohol-attributable emergency department presentations in most jurisdictions across Australia, and these increases are independent of an overall increase in presentations over time (3). This is true of NSW, where there has been a significant increase in alcohol-related emergency department presentations among people aged 16-24 in the past fifteen years (4). One explanation for this may be the nature at which young people are drinking, with national data indicating that almost one third of 18-29 year olds consume alcohol above National Health and Medical Research Council thresholds for 'risky drinking' (five or more drinks/day - 5) weekly, and over half do so monthly (1). It is therefore no surprise that alcohol is consistently associated with injury and violence among young people of this age group (6). In particular, alcohol has been identified as a factor in approximately three quarters of assaults and offensive behaviour on the street (10), and is present in 29.1% of drivers in fatal road crashes across Australia (11).

There have been concerns that mixing alcohol with energy drinks may be associated with risky drinking and alcohol related harms (7). There is a small, but growing body of international research indicating that young people are increasingly using alcohol in combination with energy drinks (12, 13). However, Australian research into this phenomenon is lacking despite widespread reports of its popularity, especially among young people in the context of a 'big night out'. At present, the current Australian evidence base is insufficient to provide clear direction for state Governments to take action in relation to health promotion or regulation.

In particular, it was identified by NSW Health that it is unclear how widespread the practice of mixing alcohol and energy drinks is in NSW, what the impacts of AED consumption is on health and behaviour at the individual and population level, and what is the threshold of energy drink that can be consumed with alcohol (i.e., proportionally and by volume) before adverse health or behavioural effects occur. The current study was designed to address these gaps in the evidence.

The intended aim of the research is to:

- determine the current status of the evidence around the health impacts of mixing alcohol and energy drinks (at the individual and population level);
- investigate the health effects of mixing alcohol with energy drinks on the NSW population (i.e., popularity of use, demographics of users, harms and effect on the health system); and,
- determine the effects of mixing alcohol and energy drinks on physiology, coordination, cognitive performance and risk-taking behaviour and determine the effects of mixing alcohol and energy drinks at different doses.

The research addresses the following questions:

1. What is the current Australian and international evidence of the effects of mixing alcohol and energy drinks? What are the gaps in the evidence? What regulations nationally and internationally have been imposed on energy drinks when intended to be consumed with alcohol?
2. What do routine data collections tell us about the harms from mixing alcohol and energy drinks? What don't they tell us? Can we determine the effects on the health system?
3. How widespread is the practice of mixing alcohol and energy drinks amongst the NSW population?
  - What population groups mix alcohol with energy drinks?
  - What are the characteristics of use (i.e., When and where does it occur? How much is drunk? In what proportions? How often? Why?)
  - What are the health and social harms experienced from mixing alcohol and energy drinks? At what amount of energy drink and what amount of alcohol do these effects occur?
  - Does use differ between metropolitan and rural communities?
4. Does AED use cause an underestimation of perceived intoxication? Does AED use cause an increase or decrease in actual intoxication outcomes via impairment on cognitive and motor performance outcomes? Does AED use increase or decrease heart rate and blood pressure? Does AED use cause an increase in behavioural risk-taking? If present, are these effects dose-dependent?
5. What is the maximum level of caffeine and other energy drink active ingredients in a standard alcoholic drink before adverse health effects occur? At what volume of energy drink and alcoholic drink do these adverse health effects occur?

A four phased approach to addressing these aims was determined appropriate, involving: a) a comprehensive review of the international literature; b) quantitative analysis of existing population level data to estimate the harms from AED use on the population and impact on the health system; c) two surveys (a web-survey and a night-time street intercept survey) with NSW residents to determine popularity of use, demographics of AED users, patterns of use and harms from use; and d) an experimental study to determine the effects of mixing alcohol and energy drinks on physiology, coordination, cognitive performance and risk-taking behaviour; and to determine the maximum level of energy drink by volume and in proportion to alcohol before adverse health effects occur. The results of the research will help build the evidence base regarding AED use in NSW, and assist the NSW Government in terms of identifying potential policy responses.

## **2. LITERATURE REVIEW**

### **2.1 Aims and Method**

The aim of the literature review was to collate and summarise the Australian and international literature on alcohol and energy drinks (AEDs) in order to detail current knowledge of the prevalence of AED use, patterns of use, motivations for use, side-effects of use, effects on alcohol consumption and associated behaviours, and also highlight current regulatory responses to AEDs in Australia and internationally. The review also aimed to identify gaps in the evidence to guide the design of other phases of the project.

Two authors (AP and AP) conducted the literature review. Both had accumulated a substantial library of research on EDs and AEDs over time – including journal articles and grey literature (such as reports) – and shared their resources with another. To ensure that their libraries were comprehensive and current, an electronic search of database PubMed was undertaken (using the search terms ‘alcohol’ and ‘energy drinks’) and a small number of journal articles that had been published recently were added to the library. The authors divided the research library (containing 221 resources) into content areas and synthesised the literature into the document.

### **2.2 Energy Drinks**

Energy drinks, such as Red Bull® and V®, are beverages designed to provide a boost of energy and enhance alertness (14). Under current Australian regulations, EDs are defined as a “non-alcoholic water-based flavoured beverage which contains caffeine and may contain carbohydrates, amino acids, vitamins, and other substances, including other foods, for the purpose of enhancing mental performance” (15).

Typical ED constituents include caffeine, amino acids (e.g., taurine), sugars (e.g., glucose and sucrose), glucuronolactone, B vitamins, and other plant and herbal extracts (e.g., guaraná and ginseng). Table 1 displays the ingredient composition of the primary marketed EDs in Australia per 250mL.

*Table 1. Ingredient composition of primary EDs marketed in Australia per 250mL*

Constituent	Red Bull®	Mother®	V®	Rockstar®	Monster®
Taurine	1000mg	1000mg	500mg	1000mg	1000mg
Caffeine	80mg	80mg	77.5mg	80mg	80mg
Glucuronolactone	600mg	300mg	62.5mg	-	5mg
Inositol	50mg	30mg	50mg	25mg	5mg
Vitamin B2 (riboflavin)	-	-	1.23mg	3.5mg	1.8mg
Vitamin B3 (niacin)	20mg	4.5mg	7.25mg	20mg	20mg
Vitamin B5 (pantothenic acid)	5mg	1.75mg	1.75mg	-	-
Vitamin B6 (pyridoxine)	5mg	0.5mg	1.15mg	5mg	2.13mg
Vitamin B12 (cobalamin)	5mcg	0.25 mcg	1.43 mcg	5mcg	5mcg
Ginseng Root Extract	-	-	-	50mg	205mg
Guarana Seed Extract	-	-	300mg	25mg	5mg

Note: As ingredient composition information was derived from product packaging rather than chromatographic analysis, labelled and actual content may be subject to variation. Additionally, quantities may differ for EDs packaged as shots (i.e., 50-60mL), capsules, or powders; - denotes the absence of the ingredient in the particular product.

### **2.2.1 Caffeine**

Consensus amongst researchers generally points to caffeine (1, 3, 7-trimethylxanthine) as the primary ingredient in EDs (16). Caffeine is one of the most widely-consumed stimulants worldwide, found in brewed and instant coffee, tea, carbonated beverages, cocoa-based products, and over-the-counter medications (17). Caffeine is a naturally-occurring product, found in the leaves, seeds, and fruits of more than 60 plants worldwide, the most common sources being coffee, cocoa beans, kola nuts, and tea leaves (18). Orally ingested caffeine generally reaches peak absorption at approximately 30 to 60 minutes with an average half-life of four to six hours (19-21). Caffeine stimulates the central nervous system by acting as a non-selective adenosine receptor antagonist (see 22 for a full review of caffeine's pharmacological actions). Adenosine receptors modulate release of central nervous system neurotransmitters, generally exerting sedative, depressant, and anticonvulsant actions (23). Consequently, caffeine's function as a competitive inhibitor results in the release of norepinephrine, dopamine, and serotonin, increasing arousal and alertness (24, 25).

Caffeine's beneficial impact on vigilance, alertness, motor performance, and fatigue is supported by a strong body of research (see 26 for a review). Participants generally record faster reaction times, reduced ratings of fatigue, and increased ratings of mental alertness following caffeine consumption (23, 27-32). However, caffeine consumption does not always result in improved performance; the relationship between caffeine and performance outcomes may vary according to methodological characteristics (e.g., task difficulty) and situational factors (e.g., fatigue, current caffeine withdrawal state, caffeine tolerance), as well as more enduring individual differences (e.g., trait anxiety) (26).

Data on the physiological and neuro-behavioural effects of caffeine suggest that it is relatively safe in adults at moderate levels of consumption (21, 33). Furthermore, caffeine's effects are typically dose-dependent, in that consumption of large doses (i.e., 400mg or more) can result in poorer

performance, greater tension, and increased anxiety (20, 25, 30). However, most Australians consume caffeine in moderation, with an average intake of 3mg/kg caffeine per day, or roughly 210mg per 70kg person (equivalent to approximately 2.7 250ml cups of instant coffee or 2.6 standard 250mL EDs) (34). The Australia New Zealand Food Standards Code (15) specifies that EDs may contain a maximum of 320mg/L caffeine, or 80mg per standard 250mL ED. As such, EDs marketed in Australia have a similar caffeine content to a standard cup of instant coffee, and less caffeine than ground coffee, with approximately 24mg/100mL caffeine in EDs, 31mg/100mL caffeine in instant coffee, and 64mg/100mL caffeine in ground coffee (15, 35).

The caffeine content of EDs may be derived from natural and synthetic sources. For example, guaraná (paullinia cupana) is commonly included in EDs due to its positive effect on mood, alertness, and memory at lower doses (i.e., 37.5mg to 75mg) (36-38). Guaraná is extracted from a native South American climbing plant (38). Guaraná seeds have a higher concentration of caffeine relative to coffee beans (39), providing a relatively longer stimulatory effect due to the slower release of caffeine (40). The Australia New Zealand Food Standards Code (15) specifies that the composition information on ED packaging must reflect the total caffeine content regardless of the source.

### **2.2.2 Taurine**

Taurine (2-aminoethane sulfonic acid) is a free amino acid widely-distributed throughout the body. Taurine is often found in animal-based foods, including dairy products, meat, and fish (38, 41, 42). It has been implicated in several metabolic processes and is argued to be a conditionally essential nutrient (43). Taurine is accumulated in high concentrations; a 70kg person has approximately 70g taurine stored within the body. While the average daily dietary intake of taurine is between 40mg and 400mg (42, 44), the Australia New Zealand Food Standards Code specifies that EDs may contain a maximum of 4000mg/L, or 1000mg per standard 250mL ED (15). However, excess taurine intake has generally exhibited low toxicity (35) and may even provide targeted therapeutic benefit at higher doses (i.e., 1500mg/day to 6000mg/day) (41, 45, 46).

### **2.2.3 Sugars**

Glucose and sucrose are essential for the normal functioning of the central nervous system (41). The brain relies on glucose and sucrose as a major source of fuel, requiring regular intake via the bloodstream due to restricted body stores (47). A standard 250mL ED contains between 25g and 32.5g of sugar (i.e., 6 to 8 teaspoons of sugar), which is roughly equivalent to the sugar content of carbonated cola soft drinks (approximately 27.5g/250mL) (48). It has been argued that the standard glucose and sucrose content of EDs functions primarily to improve the taste of EDs, as facilitated performance on attention and memory tasks typically occurs following consumption of higher doses (i.e., at least 50g) (41, 49-53). However, recent research suggests that the interaction between caffeine and glucose may contribute to the performance-enhancing effects of EDs, with facilitated performance on memory and attention tasks following co-ingestion of caffeine (75mg caffeine) and glucose (37.5mg) relative to placebo; these effects were not evident following independent glucose and caffeine consumption (54, 55).

### **2.2.4 Glucuronolactone**

Glucuronolactone is added to EDs as it functions as a natural human metabolite formed from glucose and rapidly metabolised to glucaric acid, xylitol, and xylulose (35). The average daily dietary intake of glucuronolactone is between 1.2mg to 2.3mg (56). The Australia New Zealand Food Standards Code (15) specifies that EDs may contain a maximum of 1200mg/L, or 300mg per standard 250mL ED, with most EDs in Australia containing between 2mg and 300mg glucuronolactone. Excess glucuronolactone intake has exhibited low toxicity, with no recorded adverse effects in human studies and surplus intake readily metabolised and excreted (35, 57). As the majority of previous reviews regarding the glucuronolactone content of EDs have focused on toxicological assessments, there is little evidence regarding the central nervous system effects of glucuronolactone.

### **2.3 Prevalence of ED Use**

Despite originating over half a century ago in Asia and Europe, EDs first became popular following the introduction of Red Bull® to the United States in 1997 (16). Since then, ED sales have increased exponentially. Globally, sales of EDs almost doubled between 2003 and 2008 (at 3.9 billion litres), with growth averaging 14% per year. In Australia and New Zealand, sales of EDs have increased from 34.5 million litres in 2001 to 155.6 million litres in 2010 and are predicted to rise to 237.6 litres in 2015 (an estimated rise of 53%). The US and Australasia have the highest regional consumption at 4.2 litres per person per year (33). However, it is important to keep in mind that EDs comprise a small proportion of total beverage consumption. For example, in Canada, coffee and carbonated soft drinks accounted for 17% and 16% of all non-alcoholic beverage sales in 2009 while EDs accounted for only 0.2% (58).

There is a dearth of research regarding the prevalence of ED use internationally and nationally. Available data is generally based on specific sub-populations, specifically university students, or regional samples in America, Canada, and Europe; to our knowledge there are no Australian prevalence studies. As can be seen in Table 2, between 48% and 81% of university students report using EDs in their lifetime (59-63). However, these estimates may not reflect prevalence in the general population as the ED user demographic is generally targeted in recruitment. Only one study has been conducted using probability-based sampling. Estimates of lifetime use were considerably lower, with only 31% of participants in the American community sample reporting lifetime ED use (60).

Table 2. Percentage of ED users in university student and community samples

Study	<i>N</i> <sup>#</sup>	Demographics	ED users (%)
			Last week
Stasio et al. (2011) (64)	107 (60)	Athletes ( <i>n</i> =44), Reserve Officer Training Corp cadets ( <i>n</i> =18), and undergraduate university students ( <i>n</i> =45) (age n.s)	57
Velazquez et al. (2011) (65)	585 (260*)	American university students ( <i>M</i> =18.7 years)	18
			Last month
Malinauskas et al. (2007) (66)	496 (n.s)	American undergraduate university students ( <i>M</i> =21.5, <i>SD</i> =3.7 years)	51 <sup>~</sup>
Miller (2008a) (67)	795 (413*)	American undergraduate university students ( <i>M</i> =20.02 years)	39
Miller (2008b) (68)	602 (313*)	American undergraduate university students ( <i>M</i> =19.98 years)	38
Velazquez et al. (2011) (65)	585 (260*)	American university students ( <i>M</i> =18.7 years)	38
Wells et al. (2013) (69)	1469 (781)	Bar patrons in New York City ( <i>M</i> =26.4 years)	33
West et al. (2006) (70)	253 (90*)	American undergraduate university students (age n.s)	20
			Last 12 months
Arria et al. (2011) (71)	1097 (505*)	American fourth year university students (range 20-23 years)	66
			'Ever' used
Arria et al. (2010) (72)	1060 (488*)	American undergraduate university students (age n.s)	37 <sup>^</sup>
Attila & Cakir (2011) (59)	439 (222)	Turkish medicine, sports, and arts university students ( <i>M</i> =22.8, <i>SD</i> =2.09, range 19-39 years)	48
Ballistreri & Corradi-Webster (2008) (73)	211 (114)	Argentine fourth year physical education university students ( <i>M</i> =22.6, <i>SD</i> =2.25, range 21-38 years)	65
Berger et al. (2011) (60)	946 (n.s)	Milwaukee, Wisconsin residents (range 18-92 years)	31
Marczinski et al. (2011) (74)	706 (354)	American psychology university students ( <i>M</i> =20.9 years)	81
Miller & Quigley (2012) (62)	226 (136*)	New York musicians ( <i>M</i> =22.7, <i>SD</i> =8.22, range 18-45 years)	57
Nordt et al. (2012) (75)	2,158 (1,038*)	Patients attending two San Diego Emergency Departments(n.s)	60
Oteri et al. (2007) (63)	450 (186*)	Italian medicine university students ( <i>M</i> =24.5, range 19-30 years)	57

Note. <sup>#</sup> The figure in parentheses represents the number of male participants; n.s indicates that the data was not specified; \* indicates that the *n* was calculated from the percentage and should be treated with caution; <sup>^</sup> indicates that the value represents the weighted percent of lifetime ED users in the undergraduate cohort for that year level; <sup>~</sup> indicates that the percentage refers to number of participants who reported drinking more than one ED per month in an average month.

In sum, EDs account for a small proportion of beverage sales despite their increasing popularity. To date, there are no studies examining the prevalence of ED use in Australia, with limited data available regarding the prevalence of ED use internationally. The majority of international studies have focused on ED use in specific sub-populations or regional samples, potentially resulting in inflated estimates due to specific targeting of consumer groups who fall within the ED consumer demographic. More research is needed in general population samples, as well as specific sub-groups such as university students and people under the age of 18, to ascertain how popular ED use is in Australia.

## **2.4 Effects of ED Consumption**

### **2.4.1 Performance Outcomes**

While we generally understand the functions of ED ingredients, there is limited data regarding the independent and interactive effects of these ingredients on performance. Attempts to test ED marketing claims have primarily been focused on investigating the effect of the whole drink.

Generally, marketing claims of increased alertness have been supported, with faster reaction times typically recorded on attention tasks following ED consumption (76-80) (see Table 3). It is important to note that error rates are generally not increased in these studies following ED consumption (Table 3), ruling out potential speed-accuracy trade-offs as an explanation for facilitated reaction time.

More ecologically valid measures of attention and motor performance, such as driving simulator tasks, also show performance-enhancing effects of ED consumption, with reduced standard deviation of lateral lane position (i.e., weaving of the car) and decreased number of sleep-related driving incidents (i.e., car wheel crossing the lateral lane marking) following consumption of 250mL Red Bull® (81-83). However, it must be noted that these studies assessing driving performance were supported by Red Bull GmbH through the supply of placebos and/or funding.

The facilitative effects of EDs are not only restricted to attention, with consumption of EDs (75 to 80mg caffeine) improving accuracy rates and reducing reaction time during information processing tasks (78, 84). Faster reaction times have also been recorded in verbal reasoning tasks following ED consumption (84). However, research regarding the effects of EDs on memory performance has produced mixed results. While Alford et al. (80) reported significantly improved immediate verbal memory following ingestion of 250mL Red Bull® (80mg caffeine), two studies by Warburton et al. (84) found no significant effect of 250mL ED (80mg caffeine) on immediate and delayed verbal memory or immediate spatial memory relative to placebo.

Several studies have also revealed improved aerobic and anaerobic performance following ED ingestion using double-blind, randomised, placebo-controlled, within-subjects designs. A study of 12 trained cyclists revealed significantly improved endurance performance, as measured by cycling time-trial performance, following ingestion of 500mL Red Bull® (160mg caffeine) relative to placebo (85). Similarly, significantly longer endurance time during cycling performance was recorded for 10 endurance-trained male athletes following ingestion of 500mL Red Bull® (160mg caffeine) relative to a Red Bull® placebo (minus caffeine, taurine and glucuronolactone content) (86). Both of these studies had placebo samples supplied by Red Bull GmbH and/or were financially supported by Red

Bull GmbH. Improved cycling performance has also been demonstrated in non-athlete samples, with a study of 12 healthy volunteers showing improved anaerobic performance, indicated by significantly greater maximum speed during an all-out cycling test, following ingestion of 250mL Red Bull® relative to placebo (80). Furthermore, a study of 10 male athlete university students showed significantly increased maximal oxygen uptake and time-to-exhaustion following ingestion of 6mL/kg of Red Bull® (85mg caffeine per 250mL) and Hype® (75mg caffeine per 250mL) EDs in a treadmill test (87).

Table 3. The effect of ED ingestion on simple, choice, and recognition reaction time and accuracy

Study	Design (Treatment)	Blinding	Placebo/ Control Condition	Energy Drink Condition	Simple RT	Choice RT	Recognition RT	Accuracy
Alford et al. (2001) (80)	Within-subject	Double blind	Carbonated water	250ml Red Bull®	-	↓	-	-
Childs & de Wit (2008) (76)	Within-subject	Double blind	Matched placebo capsule	200mg caffeine, 10mg taurine, 50g white willow bark, 30mg magnesium oxide	↓	↓	-	=
Gendle et al. (2009) (88)	Between-subject	Double blind	Matched placebo drink	250ml Red Bull® and Red Bull® Sugarfree	-	-	=	=
Horne & Reyner (2001) (83)	Within-subject	Double blind	Matched placebo drink	500ml Red Bull®	↓	-	-	=
Howard & Marczynski (2010)# (89)	Between-subject	Double blind	Matched placebo drink	1.8mL/kg, 3.6mL/kg, 5.4mL/kg Red Bull®	-	-	↓	=
Jay (2006) (90)	Within-subject	NS	No placebo	500mL ED (80mg caffeine, 1g taurine, 600mg glucuronolactone)	=	-	-	=
Mucignat-Caretta (1998)^ (91)	Within-subject	NS	Matched placebo drink	250mL Red Bull®	=	--	= / ↓	-
Seidl et al. (2000) (77)	Within-subject	Double blind	Matched placebo capsules	ED capsules (80mg caffeine, 1g taurine, 600mg glucuronolactone)	-	-	↓	=
Smit et al. (2004) (78)	Within-subject	Double blind	Matched placebo drink	250ml ED (75mg caffeine, 1000mg taurine, 37.5g glucose)	↓	-	-	-

Note: RT: Reaction Time; ED: Energy Drink. ↓ indicates significantly decreased RT; ↑ indicates significantly increased RT; = indicates no change in RT; – indicates that the measure was not used; ^ indicates decreased RT evident only for females; # indicates that the study received placebo samples and/or financial support from Red Bull GmbH; NS not specified; ED Energy Drink; RT Reaction Time. Simple RT tasks involve participants executing a response to the presence of a stimulus (e.g., press the button when the red circle is presented); choice RT tasks involve participants executing distinct responses for each type of stimulus presented (e.g., press the 'X' key when the red circle is presented and the 'Y' key when the orange circle is presented); recognition RT tasks involve participants executing a response for one type of stimulus and withhold a response for another type of stimulus (e.g., press the button when the red circle is presented but not when the green circle is presented).

EDs have also been shown to have positive effects on muscle-strength performance. Two studies have revealed a significant increase in total bench-press repetitions following ingestion of Red Bull® (2mg/kg caffeine) (92) and significantly improved half-squat and bench press maximal power following ingestion of 250ml Fure® (3mg/kg caffeine) relative to placebo (93). However, it must be noted that no significant effect was evident in the latter study following consumption of 250mL Fure® containing 1mg/kg caffeine.

There is some discrepancy in the literature regarding the effects of EDs on exercise performance. For example, a double-blind, crossover, placebo-controlled study of 17 physically active university students revealed no significant difference in run time-to-exhaustion following ingestion of sugar-free Red Bull® (2mg/kg caffeine) versus placebo (94)<sup>1</sup>. A double-blind, placebo-controlled, crossover study revealed that 3.57mL/kg Red Bull® resulted in no significant changes in maximal oxygen intake during cycling performance relative to placebo (95). Similarly, a single-blind, placebo-controlled, crossover study of 15 female collegiate soccer players showed no significant effect of 255mL Red Bull® (80mg caffeine) on repeated sprint performance (96) and a double-blind, placebo-controlled, crossover study of 20 football players showed no significant difference in sprint performance following consumption of AdvoCare Spark® (120mg caffeine) (97). However, it should be noted that in the former study (96), 73% participants correctly identified the active ED condition, calling into question the success of treatment condition blinding procedures. In the latter study (97), the effect of the ED on sprint performance was mediated by athletes' typical caffeine intake, showing that those participants not habituated to caffeine were more likely to demonstrate improved sprint performance following ED ingestion. However, a later study by Forbes et al. (92) of 16 physically active participants revealed no significant effect of Red Bull® (2mg/kg caffeine) on peak or average power in anaerobic cycling performance, regardless of caffeine-habituation.

Overall, the experimental evidence suggests that EDs generally improve attention and driving performance, with mixed findings regarding the effects on other cognitive processes (e.g., memory) and exercise performance. However, there are a number of considerations to note regarding these conclusions. Generally, a standard ED dose (i.e., 250mL ED containing approximately 80mg caffeine) has been administered in active ED conditions; several studies have involved administration of doses equivalent to the maximum recommended daily intake in Australia (i.e., 500mL ED containing approximately 160mg caffeine) (85, 98, 99), and in excess of the recommended dose (i.e., 750mL ED containing 240mg caffeine; 100). However, the relationship between ED and performance may be dose-dependent. For example, Howard and Marcinski (89) found that improvements in reaction time lessened as the ED dose increased from approximately 175mL to 250mL per standard 70kg person. Furthermore, no objective comparison of the cognitive and motor performance effects of ED relative to caffeine consumption has been undertaken. Thus, it is not possible at present to draw conclusions regarding the relative efficacy of caffeine versus ED consumption on performance.

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<sup>1</sup> Note that sugar free Red Bull was provided by Red Bull GmbH for this study.

In sum, ED marketing claims of improved performance and increased alertness are typically supported by research. However, the effects of EDs on performance may be dose-dependent, with higher doses resulting in reduced or no facilitation of performance. Furthermore, the positive effects of EDs may be limited to certain aspects of performance.

#### ***2.4.2 Subjective Psychological and Physiological Outcomes of ED Use***

Further evidence of EDs' positive effect on alertness can be seen in consumers' ratings of their mood following consumption. Experimental research reveals that participants generally report experiencing greater alertness, vigour, stimulation, and energy, as well as reduced fatigue and sleepiness, following double-blind administration of 0.5 to 1.5 250mL EDs (containing between 45.6mg and 136.7mg caffeine) relative to control (i.e., no beverage or water) (80) and placebo (i.e., beverage matched to active ED on taste, smell and appearance) (81, 89, 101) conditions. This perceived 'boost' in energy may be a primary motivator for use (59); ED users in a sample of American university students reported consuming EDs when they had insufficient sleep (67%), required energy (65%), while studying (50%), or during prolonged driving (45%) (66). Similarly, 28% of an Argentinean university student sample consumed EDs to enjoy an all-night party, 14% to improve sports performance, 10% for general stimulation, and 4% for studying purposes; other primary motivations included to improve the taste of alcoholic beverages (54%) and enjoy the drink (9%) (59). However, research suggests that the positive psychological effects of EDs extend beyond alertness. For example, Childs and de Wit (76) found that ingestion of ED capsules (200mg caffeine)<sup>2</sup> increased ratings of friendliness and positive mood, and decreased ratings of depression, relative to placebo capsules.

Examination of the time course of EDs' psychological effect suggests a restricted timeframe for enhanced subjective alertness. For example, Mets et al. (81) found that ratings of sleepiness were reduced following administration of 250mL Red Bull® relative to placebo only in the first hour after administration, with no significant difference in ratings according to treatment condition in the second hour. Similarly, Reyner and Horne (101) observed reduced subjective sleepiness at 30, 60, and 90 minutes following consumption of 250mL Red Bull® relative to placebo, with no significant difference at 120 minutes. However, it should be noted that participants in these studies were either sleep restricted (101) or performing under prolonged driving conditions (81). As such, the time course of EDs' subjective alerting effects in non-fatigued participants is not currently known. Furthermore, it should be noted that both studies were financially supported by Red Bull GmbH.

Findings of increased subjective alertness post consumption are generally acquired following administration of a standard ED dose (i.e., 250mL) in a controlled environment to participants tolerant to the effects of caffeine and/or EDs. ED consumers' self-reported experiences reveal positive and negative effects of ED use. One-third (29%) of ED users in an American university student sample reported experiencing weekly jolt and crash episodes (a period of increased stimulation followed by a

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<sup>2</sup> ED capsules contained 200mg caffeine, 50mg willow bark, 30mg magnesium oxide, 10mg taurine, and 375g dextrose filler.

sharp, sudden drop in energy) and one-fifth experienced headaches and heart palpitations (22% and 19% respectively) (66). Over half (57%) of those who experienced jolt and crash episodes had ingested three or more EDs (i.e., a minimum of 240mg caffeine) on one occasion. Similarly, 34% of an American ED user sample reported adverse reactions to ED consumption, the most common being jitteriness/shaking, palpitations/fast heart beat, and difficulty sleeping (75). However, it is important to note that the frequency of side-effects and the quantity of ED consumed prior to onset was not determined. Additionally, there was no indication of participants' tolerance to caffeine as estimates of daily caffeine intake were not provided. Thus, it is difficult to determine whether these adverse side-effects typically occur: (i) at certain ED doses, and/or (ii) in particular types of consumers. Furthermore, the percentage of participants who experienced adverse reactions in the latter study may be inflated, as the study comprised a convenience sample attending American emergency departments (no data was reported as to whether the visit was related to ED use).

Despite the aforementioned side-effects of ED consumption, there have been few experimental studies objectively assessing the physiological side-effects of EDs. Several studies have focused on the cardiac outcomes of ED ingestion. For example, Steinke et al. (102) found that heart rate and diastolic and systolic blood pressure were increased significantly relative to baseline within four hours of consuming 500mL ED (200mg caffeine). However, this study did not incorporate a blinded control or placebo condition for comparison. Those studies which have adopted double-blinding procedures have generally revealed mixed findings regarding the effect of EDs on heart rate and blood pressure (see Table 4). However, there is some evidence of cardiac changes following ED ingestion, with increased cardiac contractility reported after ingestion of 500mL Red Bull® (160mg caffeine) relative to placebo (103). Furthermore, Worthley et al. (104) reported increased platelet aggregation and impairment of endothelial function following ingestion of 500mL ED (200mg caffeine) relative to a control beverage. While these outcomes are recognised predictors of cardiovascular morbidity and mortality, the authors acknowledge that the clinical implications of these findings for a healthy young adult sample remain unknown.

Sleeping difficulties and insomnia are another commonly reported side-effect of ED consumption. A recent experimental study revealed that participants experienced shorter sleep time and reduced sleep efficiency during a daytime sleep following a simulated night-shift after ingestion of two portions of 250mL ED (80mg caffeine) relative to no beverage; there was no significant difference in sleep onset and slow wave sleep (90). However, the absence of a control or placebo comparison condition means that ED expectancy effects cannot be excluded. Thus, further research is required involving placebo-controlled, double-blinding procedures for objective assessment of the direct pharmacological effects of EDs on sleep.

With the exception of the aforementioned studies, information regarding ED-related side-effects has primarily been extracted from caffeine research, case studies, or poison information centre calls and emergency department visits. These studies show that short-term side-effects associated with ED use include agitation, anxiety, dizziness, difficulty concentrating, tremors, headache, diuresis, increased speech speed, sleep difficulties or insomnia, gastric disturbance, nausea, increased or irregular heart

rate, increased blood pressure, tachypnea, and paraesthesia (16, 41, 66, 102, 105-109). In more extreme clinical cases, EDs have also been associated with hallucinations (109), seizure onset and decreased seizure threshold (110), acute mania (111), psychosis (112), anaphylaxis (113), supraventricular tachycardia (105), myocardial infarction (114), cardiac arrest (115), and transient ischaemic attacks (116). It should be taken into consideration that the majority of these cases have been a result of: (i) deterioration of an existing illness, (ii) pre-existing susceptibility to the health condition, (iii) consumption of EDs in excess of recommended daily intake guidelines, and/or (iv) concomitant use with other caffeine products.

Table 4. The effect of ED ingestion on heart rate and systolic, diastolic, and mean arterial blood pressure

Study	Design (Treatment)	Blinding	Placebo/ Control Condition	Energy Drink Condition(s)	State	Heart Rate	Systolic BP	Diastolic BP	Mean arterial BP
Alford et al. (2001): Study 1 (80)	Within-subject	Double blind	- Carbonated water	- 250mL Red Bull®	Resting	=	=	=	-
Alford et al. (2001): Study 2 (80)	Within-subject	Double blind	- Carbonated water	- 250mL Red Bull®	Resting	↑	=	=	-
Astorino et al. (2011) (96)	Within-subject	Single blind	- Matched placebo	- 255mL Red Bull®	Exercise	=	-	-	-
Del Coso et al. (2012) (93)	Within-subject	Double blind	- 250mL Fure® (0mg/kg caffeine)	- 250mL Fure® (1mg/kg caffeine)	Resting	↑	↑	↑	↑
				- 250mL Fure® (3mg/kg caffeine)	Resting	↑	↑	↑	↑
Geib et al. (1994) (86)	Within-subject	Double blind	- Matched placebo (160mg caffeine)	- 500mL Red Bull®	Exercise	↓	-	-	-
			- Matched placebo	- 500mL Red Bull®	Exercise	=	-	-	-
Ragsdale et al. (2010) (117)	Between-subject	Double blind	- High calorie matched placebo	- 250mL Red Bull®	Resting	=	=	=	=
			- Low calorie matched placebo	- 250mL Red Bull Sugarfree®	Resting	=	=	=	=
					Resting	=	-	-	-
Rahnama et al. (2010) (87)	Within-subject	Double blind	- Matched placebo	- 6mL/kg Red Bull®	Post-Exercise	=	-	-	-
				- 6mL/kg Hype® (75mg caffeine/250mL)	Resting	=	-	-	-
					Post-Exercise	=	-	-	-
Worthley et al. (2010) (104)	Between-subject	NS	- Carbonated water	- 250mL sugar free ED	Resting	=	-	-	↑

Note: ↓ indicates significantly decreased heart rate/blood pressure; ↑ indicates significantly increased heart rate/blood pressure; = indicates no change in heart rate/blood pressure; – indicates that the outcome was not assessed; # indicates that the study received placebo samples and/or financial support from Red Bull GmbH; NS not specified; ED Energy Drink; BP Blood Pressure.

Emergency department and poisons information centre data generally indicate an increase over time in the number of cases reporting short-term side-effects commensurate with the increase in EDs' market size. The Drug Abuse Warning Network (DAWN), a public health surveillance system that monitors drug-related emergency department visits in the United States, showed that between 2007 and 2011 visits to the emergency department involving EDs doubled, from 10,068 to 20,783 (118). In most years since 2007 males have accounted for two thirds of ED presentations in the US and people aged 18-25 are the most common age category who present in relation to ED use (118).

In Australia, the number of calls to the New South Wales Poisons Information Centre increased from 12 in 2004 to 65 in 2010 (109). While consumers generally reported recreationally consuming 500mL ED (equivalent to the recommended maximum daily intake in Australia) some consumers reported consuming up to eight litres of ED (approximately 2560mg caffeine). Consequently, it is not unexpected that the majority of these consumers were experiencing caffeine intoxication, as evident by the primary side-effects (i.e., palpitations, tremors, agitation, and gastrointestinal upset). While these results suggest that EDs may have negative short-term health effects when consumed excessively, the relative danger of EDs compared to other caffeine products cannot be determined as the number of non-ED caffeine-related calls was not reported. This is important to determine in regards to regulation of ED ingredient composition, as it can then be determined whether the effects can primarily be attributed to the caffeine content of EDs or the interaction of ED ingredients.

In summary, experimental research generally indicates that ED users experience increased alertness, as well as other positive mood effects, following consumption. However, examination of caffeine research, case studies, and poisons information centre and emergency department data indicates that there are potential negative short- and long-term side-effects to ED consumption. While several commissioned inquiries (35, 57) have established the independent safety of the primary ED ingredients, further research directly examining the safety of the 'whole' beverage is required. Specifically, this research should focus on determining the frequency of side-effects and the ED doses at which they are likely to appear.

### ***2.4.3 Behavioural Risk-Taking Outcomes of ED Use***

Another area of concern for health professionals and researchers is the potential association between ED use and risk-taking. ED users are generally more likely to have alcohol-related problems, smoked cigarettes, used prescription drugs recreationally, used illicit drugs, engaged in physical violence, or completed a risky dare (67, 72, 119). However, it is unknown whether this association between ED use and risk-taking is because people high in risk-taking propensity are attracted to ED use and/or whether ED use causes increases in risk-taking behaviour (120). For example, ED users typically differ from non-ED users in demographic characteristics, in that they are more likely to be male and younger, and in personality characteristics, in that they typically report higher sensation-seeking and impulsivity (62, 72).

EDs may attract a riskier, more impulsive consumer due to their public image, which is generally centred on associations with sport, masculinity, and risk-taking. Miller (67) argues that these

marketing strategies encourages consumers to vicariously participate in risky, extreme behaviour through their personal ED use. However, there has been no experimental research objectively measuring risk-taking behaviour following ED consumption. Future research involving measurement of risk-taking following ED consumption could identify whether the personality of the consumer or the pharmacological effects of the drink are responsible for higher rates of risk-taking.

## 2.5 Alcohol and EDs

Research indicates that alcohol became a popular mixer with EDs (AEDs) around the early 2000s, and pre-mixed or 'ready-to-drink' AEDs were introduced to the market around 2003 (14, 16, 121). The two types of AEDs consumed in Australia are those that are pre-mixed and sold in bottle shops and some licensed venues, and those that are hand mixed by bar staff and consumers themselves. The most widely recognisable pre-mixed AED in Australia is Pulse, a 300mL can that contains approximately 21mg of caffeine and has an alcohol content of 7%. The most popular hand-mixed AEDs are those mixed with vodka and Jagermeister® (known as 'Jagerbombs'<sup>3</sup>). These usually contain one shot of alcohol (10g or 30mL) mixed with either half or a full can of ED (125mL or 250mL; approximately 40mg or 80mg caffeine) which has an alcohol content of between 5% and 10% depending on the quantity of the mixer. It is important to keep in mind that pre-mixed AEDs account for a minority of AED consumption but many studies do not differentiate between the two types.

## 2.6 AED Prevalence

### 2.6.1 International Studies

Only two general population studies have been conducted examining the prevalence of AED use, and both show that at a population level, per capita consumption of AEDs is relatively low. The Canadian Alcohol and Drug Use Monitoring Survey (CADUMS), a national telephone survey of 13,615 people over the age of 15, introduced questions about AED use for the first time in 2010. Of those who had consumed alcohol in the past month, only 2.5% had consumed an AED in the past month; however, this was elevated to 11% among 18-24 year olds, with use among males slightly higher (12.6% versus 9.1%) (122). A second study, with a much smaller sample, which involved 946 people accessed via random-digit dialling in the US, found that 6% of the total sample had consumed an AED in the past year and 20% of ED users had consumed an AED in the past year (60). The results of these studies should be treated with caution given that no information was provided on the demographic break-down of the sample, and it is very likely that people aged between 18 and 35 were under-represented given the random-digit dialling nature of the data collection. In addition, it is important to bear in mind that the Canadian and the US studies report on different time frames (the Canadian study reported past-month use and the US study reported past-year use).

The remainder of AED prevalence studies have been undertaken in specific sub-populations, such as university students, providing more detailed information about rates of use, consumption patterns and

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<sup>3</sup> A Jagerbomb is a shot of Jagermeister® mixed with an ED. The shot of Jagermeister® is typically dropped into a glass of ED and the drink is 'chugged' (consumed rapidly) until it is finished.

outcomes for specific sub-groups. A face-to-face survey conducted among fourth-year university students in the US, published in 2011 by Arria et al. (71), found that 66% had 'ever' used an AED. A similar study published by Miller in 2012 (67) involving anonymous self-completed surveys among 648 sexually active university students in the US, found that 29% of students had 'ever' used an AED. In terms of past year use, a US study conducted by Woolsey and colleagues published in 2010 (123, 124) involving a self-completed survey with 401 athletes found that 37% had consumed an AED in the past year.

Most surveys involve self-report of 'past month' use of AEDs. An online survey conducted among 585 US university students in 2009, conducted by Velazquez et al. (65) found that 15% had consumed an AED in the past month, while a similar study in Canada conducted by BAChe and Stockwell (125), using the same online methods among 465 students (and also reporting data collected in 2009) found that 23% had used an AED in the past month. A web-based survey conducted across ten different universities in the US in 2006, conducted by O'Brien et al. (126), with a much larger sample than other studies ( $N=4,721$ ), found that 24% had used an AED in the past month. An anonymous questionnaire of 500 students in Italy, published in 2007 by Oteri et al. (63), found that 48% had consumed an AED in the past month.

Finally, a US study published in 2010 by Thombs et al. (127) that involved interviews with 697 patrons as they exited licensed venues between 10pm and 3am, found that 13% had consumed AEDs or alcohol and EDs consumed separately in the previous 12 hours. While this study tells us little about the popularity of AEDs in general, it does give us some information about the proportion of people who consume AEDs when they attend licensed venues in the US.

### **2.6.2 Australian Studies**

The only Australian published study reporting on prevalence was conducted by Peacock et al. in 2011 (128, 129). Using a purposive sampling approach, these authors recruited general community members over the age of 18 to a web-based survey via posters displayed in Tasmania, media reporting and social networking sites. Four hundred and three of 963 participants (42%) reported consuming an AED in the past six months. An important consideration when interpreting these findings is that the likely demographic of AED users (18-35 years) were deliberately targeted through specific recruitment strategies (such as advertising in licensed venues) and as such this figure is likely to be much higher than population-based estimates. In addition, the sample was heavily weighted towards Tasmanians. Nonetheless, this study is the best available representation of the popularity of AEDs in Australia among the target group. The only other Australian study reporting on AED consumption was drawn from interviews with 693 regular ecstasy users and revealed that 70% had consumed an AED in the past six months (130). While this study is limited in its generalisability, it gives some indication as to the high popularity of AEDs among illicit stimulant users.

Table 5 details the results from these prevalence studies. It is important to bear in mind that some studies use different time periods, that is, some report on use in the last month, some report last year consumption, and others report lifetime use.

Table 5. Percentage of AED users in university student and community samples

Study	N <sup>#</sup>	Demographics	AED use (%)
			Last month
Velazquez et al. (2012) (65)	585 (257)	Web-survey, US university students ( <i>M</i> =18.7 years)	15
Miller (2012) (131)	648 (340)	Self-administered survey, US university students ( <i>M</i> =20.14 years)	29
Brache and Stockwell (2011) (125)	465 (205)	Web-survey, Canadian university students ( <i>M</i> =24 years)	23
O'Brien et al. (2008) (126)	4721 (1841)	Web-survey, US university students ( <i>M</i> =20.4 years)	24
Oteri et al. (2007) (63)	450 (185)	Self-administered survey, Italian university students ( <i>M</i> =24.5 years)	48
Wells et al. (2013) (69)	1469 (781)	Bar patrons in New York City ( <i>M</i> =26.4 years)	17
			Last six months
*Peacock et al. (2012) (128, 129)	963 (375)	Web-survey, Australian community sample, largely comprised of Tasmanian residents ( <i>M</i> =23.1 years)	42
*Sindich and Burns (2011) (130)	693 (402)	Regular Australian ecstasy users ( <i>M</i> =24 years)	70
			Last twelve months
Woolsey (2010) and Woolsey et al. (2010) (123, 124)	401 (144)	Self-administered survey, US university students, athletes ( <i>M</i> =19.8 years)	37
			'Ever' used
Arria et al. (2011) (71)	1097 (505)	Self-administered survey, US university students (age range: 20-23 years)	66
Miller (2008) (67)	795 (413)	Self-administered survey, US university students ( <i>M</i> =20.2 years)	26
			'Tonight'
Thombs et al. (2010) (127)	693 (493)	Bar patrons from the US, exiting licensed venues between 10pm-3am ( <i>M</i> =22.8 years)	13

Note: <sup>#</sup> The figure in parentheses represents the number of male participants.  
 \* Denotes Australian studies

In summary, only two population studies have been undertaken (both in North America) and these show relatively small per capita consumption of AEDs. These studies are limited by their random-digit dialling nature and are likely to under-represent young people and those who only have mobile phones. Studies undertaken among particular sub-groups are useful for understanding the popularity of AED use among the target demographic; however, these purposive sampling approaches rely on self-selection and this means people who do not respond to particular advertising techniques are missed in the sample. North American university samples show a general prevalence of past-month AED use between 15% and 30%, with most showing that around one quarter of students had used an AED in the past month. An Italian study indicates that perhaps use in Europe might be higher (almost 50% of a university sample) but much more work is needed to contextualise this finding. Two Australian studies showed that nearly half of a community sample and 70% of regular ecstasy users had used an AED in the past six months. More Australian prevalence data is needed, both at a population level and among specific sub-groups of AED users.

## **2.7 AED Consumption Patterns**

There has been a small amount of Australian and international data collected on AED consumption patterns, including quantity and frequency of use, though this is an area where more research is needed. Survey data shows that AEDs are most often consumed fortnightly to monthly and are generally consumed in a moderate fashion; however, qualitative data suggests that a smaller group of consumers drink higher quantities of AEDs. A limitation of previous research is that most studies do not specify the quantity of EDs (i.e., whether one ED unit is equivalent to 125mL, 250mL or even 500mL).

### **2.7.1 International Studies**

BAChe and Stockwell (125) reported that AED consumers in a Canadian university student population (who completed a web-based survey in 2009) typically consumed AEDs on two days in the past month and consumed an average of two AEDs on a typical drinking occasion. This study found that students were more likely to 'hand mix' their AEDs (61%) as opposed to purchase and consume pre-mixed AEDs (39%). Popular locations for consuming AEDs among this sample included at a party (44.6%), at a bar (38.4%), at a friend's home (32.4%), at school (16%) and in one's own home (15.7%). These participants were more likely to purchase AEDs (including hand-mixed AEDs) at liquor stores (61.2%) than at bars (38.8%) (125), but this finding might be partially explained by the fact that many participants were under the legal drinking age and so not permitted in licensed venues.

An Italian university study published by Oteri et al. in 2007 (63), showed that over a third of the sample consumed AEDs at least three times in the past month. A US university study conducted by Woolsey and colleagues and published in 2010 (123, 124) showed that 61.4% of AED-using athletes consumed three or more AEDs in a typical session, with an average of 8.21 AED sessions per year. A third US university study, published by Arria et al. in 2011 (71), showed that 25% of AED users consumed these beverages occasionally, 27.6% used monthly, 10.4% used weekly and 2.6% reported daily or almost daily use.

### 2.7.2 Australian Studies

A sample of Australian ecstasy users reported consuming AEDs weekly (19%), monthly (26%) and less often (28%), and on their last occasion respondents had consumed a median of three (range 1-13) AEDs (130). Among AED users recruited through Peacock et al.'s recent Australian web-survey (128), 77% reported mixing these beverages infrequently (i.e., monthly or less) and only 3% reported consuming AEDs more often than once week. During sessions of AED use, participants reported typically consuming 2.4 EDs with 7.1 standard alcoholic drinks, with AEDs making up less than half of their total alcohol consumption. Vodka and Jagermeister® were the two most popular mixers with EDs and favourite locations for AED use were nightclubs (42%), bars and pubs (30%), and private residences (11% at parties and 10% at homes). During typical sessions of AED use, 27% of the sample reported consuming their first AED between 6-9pm, 52% reported consuming their first AED between 9pm-12am and 15% reported their first AED use after midnight.

In contrast, a recent Australian qualitative study undertaken by Pennay and Lubman (58, 132) that involved interviews with 10 regular consumers of AEDs found that AEDs were as popular in private homes and pubs as they were in nightclubs. Participants reported two main consumption patterns. One sub-group of AED consumers reported the consumption of between two and five AEDs over the course of the night, starting with one or two AEDs as an initial "booster" early in the evening (see also 121), followed by a period of non-AED alcohol use (such as beer, wine or spirit consumption) and then consumption of around two AEDs later in the evening when they began to feel tired or were drawn to a beverage with a sweeter taste. The second sub-group of AED consumers reported drinking AEDs constantly throughout their session of alcohol use, consuming between 8-12 AEDs on a typical night out.

In summary, there has been a moderate amount of research, including university studies, an Australian web-survey and an Australian qualitative study, showing that most AED consumers report consuming these beverages fortnightly to monthly and consume between two and three AEDs per session. A major limitation of these studies is that most do not specify the volume of one ED 'unit'. There does appear to be a small sub-group of AED users who consume these beverages in greater amounts and at greater frequency. For example, one university study showed that 10% of users consume AEDs at least weekly and one qualitative study suggests that a smaller number of AED users consume upwards of eight AEDs per session. More research is needed among this sub-group, specifically identifying the typical characteristics of these consumers in order to facilitate targeted education regarding AEDs and their associated harms. Vodka and Jagermeister® are the most popular beverages to combine with EDs and AED consumers are more likely to hand-mix these beverages than purchase pre-mixed AEDs. Interestingly, AEDs appear to be popular for consumption within homes, as well as in licensed venues. Three Australian studies have shown that AEDs are popular for consumption earlier in the evening, but that some consumers will also return to AED use later in the evening.

## **2.8 Socio-demographics and Characteristics of AED Users**

### **2.8.1 International Studies**

North American survey research shows that AED users tend to be Caucasian, male and younger. For example, Berger et al. (60), who conducted a random-digit dialling telephone survey of 946 US residents, found that ED users (compared with non-ED users) were significantly more likely to be male, Caucasian and younger (i.e., 18-29 years old). AED users, when compared with ED users, were also significantly more likely to be younger (18-29 years). BAChe and Stockwell (125) reported that among 465 Canadian university students, AED users were more likely to be young (an average of 21.7 years compared to 24.0 years in the broader sample) and Caucasian (85% compared with 81% in the broader sample). While BAChe and Stockwell found no significant difference in AED use according to sex, O'Brien et al. (126) found that US university students who consumed an AED in the past month were more likely to be male (47% compared to 37% in the broader sample) and Caucasian (84% compared with 78% in the broader sample).

A recent study involving 1469 interviews with bar patrons in New York City (69) found that males (19.6%) were more likely to have consumed AEDs in the past month than females (14.3%) and AED consumers (average age 25.7 years) were younger than non-AED consumers (average age 26.7 years). This study also found that individuals sampled at gay venues (25.6%) were more likely to report consuming AEDs than those sampled at college, lesbian, indie rock, electronic, or warehouse venues (15.3%).

### **2.8.2 Australian Studies**

There has been very little research conducted examining the demographics of Australian AED users. A qualitative study conducted by Jones in 2008 (133), that involved focus groups with 95 young people aged 12-17 years, found that participants aged 15-17 were much more familiar with AEDs than participants under the age of 15. As such it appears the age group most like to consume AEDs are those aged 15-29 years, but much more work is needed to confirm this, particularly among people under 18 years of age.

### **2.8.3 Substance Use and Risk-Taking Characteristics – International Studies**

Five studies have shown that AED users consume more alcohol in general than non-AED users. BAChe and Stockwell's Canadian web-based survey (125) showed that AED consumers were heavier drinkers than non-AED users in regards to typical quantity and frequency of use, and were also more likely to consume illicit stimulants such as cocaine and methamphetamine. O'Brien et al.'s survey among students at ten US universities (126) showed that AED users had almost twice as many heavy episodic drinking days in the past 30 days and reported twice as many episodes of weekly drunkenness compared with non-AED users. This study also showed that AED users drank 5.8 drinks during their typical drinking sessions compared to non-AED users who typically consumed 4.5 drinks. A study among US athletes by Woolsey et al. (123, 124) showed that AED users drank more often, consumed more alcohol per occasion, 'binge' drank more often, drank considerably more alcohol per

occasion, and consumed more than double the amount of alcohol in the previous year, compared with non-AED users. A US university study by Velazquez et al. (65) found that for each extra day of ED use in past month, the likelihood of past month alcohol use increased by 80%, heavy drinking by 80% and past month AED use by 90%. Finally, Thombs et al.'s portal study (127), which involved interviewing and breathalysing patrons leaving licensed venues, showed that patrons who had consumed AEDs were over three times more likely to leave the bar with a BAC of 0.08% or more compared to non-AED consumers. These consumers were also more likely to exit the venue later in the evening, drink for a longer period of time and consume more drinks compared to non-AED consumers.

One US survey study conducted by Arria et al. (71) identified a link between AED use and alcohol dependence. This study reported that university students who consumed AEDs at least weekly (as opposed to students who consumed AEDs monthly or less) consumed alcohol more frequently in the past year, consumed more alcohol per day and were more likely to meet criteria for alcohol dependence. While the authors propose that these findings support suggestions that ED users are at increased risk for substance-use problems, it should be considered that this finding might be an outcome of heavy drinkers using AEDs in their repertoire of intoxication.

Two studies by BAChe and Stockwell (125) and Woolsey et al. (123, 124) have shown that AED users score significantly higher on a risk-taking propensity scale than non-AED users, suggesting a significant association between the two factors; however, it is unclear whether this is because people with risk-taking propensity are more likely to consume AEDs or whether increased alcohol consumption during AED sessions facilitates this risky behaviour (120). BAChe and Stockwell's (125) web-based survey of Canadian university students showed that frequent AED consumers were twice more likely to engage in risky practices, such as drink driving, riding in the car with a driver who had been drinking and being hurt or injured, than infrequent AED users (125). O'Brien et al.'s (126) web-survey found that university students who reported consuming AEDs were more likely to be taken advantage of sexually, take advantage of someone else sexually, ride with a driver who was under the influence of alcohol, be hurt or injured, require medical treatment, and drive a car while under the influence of alcohol. Finally, a US university study conducted by Miller (131) showed that AED users were significantly more likely to report recent engagement in casual sex or intoxicated sex than non-AED users.

In summary, AED users are more likely to be Caucasian, male and younger, but little is else is known about the socio-demographics of AED users, especially in Australia where research is sparse. Further research should be undertaken among 18-30 year old Australians to gather more information about the demographic characteristics of AED users. Research is also needed among people under 18 years as little is known about the popularity of AED use and characteristics of AED users among this group in particular.

Research shows that AED users are more likely to exhibit riskier drinking practices, including the tendency to drink more frequently and drink higher quantities of alcohol use per session, and have a higher propensity for risk-taking and engage in more risk-taking behaviours relative to non-AED users.

However, this does not necessarily mean that AED consumption facilitates risk-taking; it could also mean that people who are heavy drinkers and risk-takers are more likely to consume AED. This relationship needs more research attention.

## **2.9 Motivations to Consume AEDs**

A range of research has investigated the benefits, or motivations, for use of AEDs. This encompasses survey research from the US, Brazil and Australia and two Australian qualitative studies.

### **2.9.1 International Studies**

A large web-survey conducted across 10 universities in the US, conducted by O'Brien et al. (126), found that the greatest motivations for consuming AEDs were to hide the flavour of alcohol (55%) and feel and look less drunk (15% and 5% respectively). A smaller web-survey conducted by BAChe and Stockwell (122) found that Canadian students consumed AEDs because they liked the taste (35%), for increased energy (27%), to stay awake while drinking (20%), to party longer (18%), to get a buzz quicker (9%) and to drink more without getting drunk (3%). A study of 136 ED users from Brazil, conducted by Ferreira et al. in 2004 (134), found that those who combined alcohol with energy drinks experienced happiness (38%), euphoria (30%) and increased physical vigour (24%).

### **2.9.2 Australian Studies**

The only Australian web-based survey to be published, by Peacock et al. (128), found that AED consumers are motivated by a range of functional, hedonistic, availability, social and taste factors. The most popular reasons for consuming AEDs among this sample were to feel more energetic (70%), because of the taste (69%), to stay out later (54%), to enjoy the combination of effects (49%), to have more fun (46%), to increase alertness (45%), to get a bigger buzz (42%), to facilitate intoxication (32%), to improve mood (31%) and to feel more social (30%).

Qualitative interviews conducted with ten young consumers of AEDs living in Melbourne, Australia, by Pennay and Lubman (132, 135), found that consumers combined alcohol with EDs to increase wakefulness and energy, because they enjoyed the taste, because EDs counteracted the inebriating effects of alcohol, because EDs facilitated intoxication and because the consumption of 'bombs' in a group facilitated sociability. A study that involved focus groups with 21 university students from Wollongong, Australia, conducted by Jones and Barrie (121), found that the most popular motivations for use of pre-mixed AEDs were increased intoxication, taste, a greater psychoactive buzz, because they are 'cool' and greater convenience and portability. Table 6 synthesises this literature and shows the most popular motivations for AED use.

*Table 6. Self-reported motivations for AED use in order of frequency*

Motivation	% (showing the maximum cited across the articles)
(1) Energy, wakefulness and stimulation	70
(2) Taste	69
(3) To stay out later and keep drinking	54
(4) To enhance alertness, reduce impaired drunkenness or facilitate desired drunkenness	49
(5) To enhance enjoyment	46
(6) To get a better psychoactive hit or quicker buzz	42
(7) To feel happier	38
(8) To increase intoxication	32
(9) To improve mood	31
(10) To experience euphoria	30
(11) To increase sociability	30
(12) The social status of AEDs makes them a 'cool' drink to consume	-
(13) The portability and convenience of pre-mixed AEDs	-

\*The final two motivations were based on qualitative research with no percentages offered.

The primary motivations to use AEDs can be synthesised into four main points: a) the stimulant properties of caffeine facilitate wakefulness and energy; b) the sweet, palatable taste of AEDs provide a more appealing beverage and masks the flavour of alcohol, which is particularly appealing for young people; c) drowsiness and feelings of inebriation are reduced, and a more desirable intoxication state is facilitated; and d) the consumption of bombs in a 'chugging' context along with the sweet taste (and/or masking the flavour of alcohol) of AEDs and hyperactivity facilitated by caffeine may increase alcohol consumption and intoxication (and intoxication is sometimes the intention of going out and drinking for young people). It is important to note that not all of these motivations are true for all consumers and it may be that a proportion of consumers are using AEDs for one, several or all of these motivations.

### **2.9.3 Do AEDs Reduce Impairment and Increase Alertness?**

As noted above, some AED consumers choose to combine alcohol with EDs because it reduces their subjective perceptions of inebriation and facilitates alertness and control. It is suggested that the stimulant effects of EDs reduce alcohol's depressant, sedative, and impairing effects on performance (95). As the sedation effects of alcohol (e.g., fatigue, drowsiness) indicate to the consumer their level of intoxication, consumption of EDs with alcohol may mean that consumers are less able to accurately estimate their level of intoxication and impairment. A number of experimental studies have attempted to unpack this relationship.

The primary ingredient thought to be behind EDs' reduction of alcohol-induced impairment is caffeine. Caffeine is often used by alcohol consumers as a means of 'sobering up', as the stimulant effects of

caffeine are thought to compensate for alcohol's sedation effects (136). In several studies caffeine has compensated for reduced alcohol impairment in laboratory-based measures of reaction time (137-139), psychomotor speed (140), psychomotor performance (141, 142), behavioural control (136, 143, 144), decision-making (145), and processing speed and memory (146-148). Furthermore, caffeine has been shown to reverse the effects of alcohol on sleep latency (148), as well as brake latency, during a driving simulator task (149).

However, these results do not necessarily mean that caffeine fully compensates for alcohol's negative effects on performance; in some cases caffeine has partially reduced the effects of alcohol, with some impairment still evident (e.g., 136). Furthermore, other studies have showed that caffeine does not affect, or further impairs, performance following alcohol consumption (136, 138, 149-153). For example, Attwood et al. (136) found that caffeine (2.0mg/kg) ingested with 0.6g/kg alcohol did not affect alcohol-induced impairment of behavioural inhibition, as assessed via a Go/No-Go task, and worsened alcohol-induced impairment of behavioural interference, as indexed via accuracy on a Stroop task. Similarly, a driving simulator study revealed that the addition of caffeine (approximately 383mg) to beer (target 0.12g% BAC) did not reduce alcohol-induced impairment in attention and driving performance (150).

Similarly, studies examining participants' self-reported intoxication after caffeine and alcohol show mixed findings. Several studies have revealed equivalent subjective ratings of mood and intoxication (i.e., 139, 149) following ingestion of alcohol independently or combined with caffeine. For example, Marczinski and Fillmore (151) reported no significant difference in stimulation and sedation ratings following ingestion of alcohol (0.65g/kg) with or without caffeine (2.0mg/kg and 4.0mg/kg). However, a later study revealed that co-ingestion of caffeine (2.0mg/kg) with alcohol (0.65g/kg) reduced perceived intoxication ratings relative to alcohol alone (154). It should be noted that co-administration of a higher caffeine dose (4.0mg/kg) with alcohol did not significantly affect ratings relative to alcohol only in this study.

Thus, there is conflicting evidence regarding the effect of caffeine on performance and perception of intoxication after alcohol consumption. While it could be inferred that EDs mixed with alcohol would show a similar pattern of results, there is research to suggest that other ED ingredients may have an interactive effect with alcohol (155, 156). For example, Ginsburg and Lamb (155) found that taurine pre-treatment reduced alcohol-induced changes in locomotor activity in mice, and Mattucci-Shiavone and Ferko (156) reported that administration of taurine to Sprague-Dawley rats increased alcohol-induced sleep time. As such, examination of the 'whole' beverage effect with alcohol is crucial to determine the relationship between AED consumption, performance outcomes, and perception of intoxication.

Those studies which have examined the effect of AED on performance outcomes have generally shown that EDs generally do not alter alcohol-induced impairments in performance (74, 95, 157-159). For example, Ferreira et al. (95) observed similar motor coordination and reaction time performance following consumption of alcohol (0.6g or 1.0g/kg) with or without 3.57mL/kg Red Bull®. Marczinski, Fillmore, Bargett, and Howard (74) found that co-ingestion of EDs (3.57mL/kg) with alcohol (0.65g/kg)

did not reduce alcohol-induced deficits in response inhibition. A later study by Marczinski et al. (159) also revealed no significant difference in information processing and motor coordination following ingestion of alcohol (0.65g/kg) with or without EDs (3.57mL/kg).

However, there have been some cases to the contrary, with several studies showing that ED consumption reduces alcohol-induced impairment of response execution and cognitive interference (74, 157). Furthermore, it must be noted that there has been relatively little examination of the dose-dependent relationship of AEDs in regards to performance outcomes, as the majority of experimental studies have involved administration of a standard ED dose (i.e., approximately 250mL ED per 70kg person) with a moderate to high alcohol dose (0.071% to 0.10% BAC). There have been no studies systematically assessing the interactive effect of EDs and alcohol at varying doses. Furthermore, as aforementioned, Australian AED consumers report typically ingesting 2.4 standard 250mL EDs in their typical AED drinking sessions (129). Subsequent research assessing the effects of AED consumption at higher doses is required to increase the generalisability of results to real-life AED consumption.

The few studies assessing the subjective intoxication outcomes of AED use have yielded mixed results regarding whether co-ingestion results in increased or equivalent intoxication ratings compared to alcohol alone. For example, an early study by Ferreira et al. (95) showed that AED consumption reduced perception of impaired motor coordination and dry mouth relative to alcohol consumption. However, ratings of other prominent intoxication symptoms (e.g., 'tiredness', 'dizziness') were similar following alcohol and AED consumption. Later studies have, with the exception of Alford et al. (157), generally focused on direct ratings of intoxication and impairment, as well as ratings of stimulation, sedation, and fatigue. Across these AED studies, intoxication, impairment, and sedation ratings have not differed significantly following consumption of alcohol (.025% BAC to .089% BAC) with or without EDs (1.82mL/kg to 3.57mL/kg).

Greater stimulation ratings have been recorded following AED consumption relative to alcohol consumption (74, 159), as well as reduced mental fatigue (159) under higher alcohol (0.65g/kg) and ED (3.57ml/kg) doses; no significant difference on these indices was observed at lower AED doses (i.e., 0.91mL/kg alcohol and 1.82mL/kg ED) (160). However, conclusions of greater AED-induced stimulation in the former study (160) was based on examination of the descriptive data rather than direct statistical comparison of the AED and alcohol groups. In the latter study (159), stimulation and mental fatigue ratings prior to beverage administration were not collected. Thus, baseline differences in stimulation and mental fatigue in the AED and alcohol conditions may have contributed to those differences evident following beverage administration. Further research directly assessing the statistical difference in subjective ratings of stimulation and mental fatigue is required, particularly under conditions where the participants' subjective state prior to beverage consumption is taken into account.

While there are mixed findings, it appears that some research does suggest that consumers may believe they are more stimulated and less fatigued after consuming AEDs. Several researchers have argued that the increased perception of stimulation reduces the sedation effects of alcohol which act as an indicator of intoxication (119, 161). If this was the case, it could be expected that ratings of

'intoxication', 'impairment', and 'sedation' would be reduced following AED consumption. However, as aforementioned, these ratings generally do not differ for AED and alcohol conditions.

In summary, alcohol-induced deficits in performance are generally similar following AED and alcohol consumption. These results suggest that AED consumption does not alter consumers' actual intoxication levels. However, ratings of aspects of intoxication relating to stimulation are typically higher after AED consumption. Some researchers have inferred that AED consumers underestimate their intoxication, as the sedation cues indicating intoxication are reduced due to the increased feeling of stimulation. However, ratings of sedation and intoxication are typically similar following AED and alcohol consumption. Further examination of the dose-dependent effect of alcohol and ED co-ingestion in regards to perception of intoxication may clarify these effects.

#### ***2.9.4 Do AEDs Facilitate Increased Alcohol Intake?***

One of the primary motivations for AED use, as identified above, includes the facilitation of intoxication through increased alcohol use. At least two studies support this finding by showing that AED consumers are likely to ingest greater quantities of alcohol in AED sessions relative to alcohol sessions. An Australian study found that AED users consumed on average 7.1 standard drinks during sessions of AED use compared to 6.5 drinks during alcohol-only sessions (128, 129) and a study of Canadian university students showed that AED users consumed an average of 8.6 drinks during AED sessions and 4.7 drinks during non-AED sessions (162).

However, some studies show the opposite result, or show that sources of caffeine other than EDs are associated with greater alcohol intake. A study of American university athletes showed AED users typically consumed 8.6 drinks during alcohol-only sessions compared to 6.3 drinks when consuming AEDs. A study that involved interviews and a breathalyser test with 256 bar patrons found that those who had consumed alcohol with cola had significantly higher blood alcohol content than those consuming alcohol alone and AEDs; however, a major limitation of this study was that the AED group contained only 10 patrons (163). In contrast, a second study by the same authors, which re-analysed survey and breathalyser data from 413 bar patrons, found that those who consumed alcohol with diet cola had higher blood alcohol content (mean BAC 0.133) than those who had consumed alcohol alone (mean BAC 0.073) or with regular cola (mean BAC 0.097); the difference in blood alcohol concentration between those who had consumed alcohol with diet cola versus EDs was not significant. Furthermore, there was no significant association between number of AED drinks and patron intoxication (164). It should be noted that in this study, only 25 people had consumed an AED and 26 had consumed alcohol with diet cola, meaning that the sample sizes of these two groups were quite small given the overall sample size. Finally, a study of 549 Dutch university students showed that those who consumed cola with alcohol during their last session of alcohol use drank significantly more alcohol than those who had consumed alcohol-only or AEDs (165)<sup>4</sup>. It is worth noting that

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<sup>4</sup> One of the authors of this study has received research funding from, and has acted as a scientific advisor for, Red Bull GmbH.

studies that compare different beverages or 'user types' are limited in that individual differences in the consumers (i.e., personality or demographics) might account for the findings.

Despite several survey-based studies being undertaken, no objective measurement of alcohol intake following AED consumption has been conducted, though animal studies have revealed that caffeine consumption increases subsequent alcohol consumption (166). Future research involving objective measurement of alcohol intake following AED and alcohol consumption could clarify the relationship between AED use and subsequent alcohol intake.

Several potential explanations for self-reported increases in alcohol intake following AED consumption have been proposed. The first theory is based on the idea that AED use results in increased stimulation. Based on this argument, consumers may believe they are able to drink more alcohol because the sedation cues which indicate their level of intoxication (e.g., fatigue) are disguised by their perception of increased stimulation (119, 125, 161). Examination of AED motivations suggests that some consumers drink AEDs to feel more energetic, maximise their intoxication, and increase their alcohol intake (see Section 9). However, there has been no objective measurement of alcohol intake following AED ingestion and no assessment of the relationship between alcohol intake and subjective ratings of stimulation. As such, there is no evidence at present to suggest a causal relationship between increased stimulation and increased alcohol intake following AED consumption.

The second hypothesis is based on the same concept, except the increased stimulation following AED consumption may decrease consumers' fatigue, extending the drinking period, and increasing the opportunity for further alcohol intake. As aforementioned, a portal study revealed found that bar patrons who had consumed AEDs had been drinking for significantly longer than those who ingested alcohol or alcohol and EDs independently (127). Furthermore, examination of AED motivations reveals that the majority of users consume AEDs to reduce fatigue and stay out later (see Section 9). However, there is no objective data available comparing AED users' typical drinking session length when drinking alcohol compared to AEDs.

Consumption of alcohol primes consumers to drink more alcohol. Thus, the third hypothesis is based on the idea that EDs enhance the reinforcing, positive aspects of alcohol consumption, increasing consumers' motivation to drink more alcohol. A recent study showed that 'desire for more alcohol' ratings were significantly higher following co-ingestion of EDs (1.82mL/kg) with alcohol (0.91mL/kg) relative to baseline at 10, 20, 40, and 60 minutes post-ingestion, whereas ratings in the alcohol condition were only significantly higher than baseline at 10 and 20 minutes post-ingestion. In contrast, another study revealed no significant difference in ratings of alcohol craving following consumption of alcohol (0.6g/kg) independently and combined with caffeine (2.0mg/kg) (136, 160). Thus, there is mixed support for the hypothesis that EDs increase consumers' motivation to drink by boosting alcohol's reinforcing, positive effects. Furthermore, there is no research investigating whether this potential increased motivation to drink following AED consumption translates into increased alcohol intake.

Fourthly, Arria et al. (72) argue that AEDs are similar to ‘alcopops’, in that the sweet taste of EDs masks alcohol’s flavour, allowing greater alcohol intake. However, examination of AED motivations suggests that consumers mainly use AEDs for the pleasurable taste of the combined beverage, with only a small proportion using AEDs to hide the aversive flavour of alcohol (see Section 9). It is important to note that there has been no research assessing consumers’ intentions when using AEDs to hide alcohol’s flavour. It could be that enjoyment of the taste of AEDs leads to further consumption; however, as noted earlier, the majority of AED users only consume two or three AEDs per session.

In summary, self-report data yields conflicting findings regarding whether AED users consume more alcohol in AED drinking sessions relative to alcohol drinking sessions and there has been no objective measurement of alcohol intake following AED consumption. Despite these mixed results, researchers have proposed several explanations for increased alcohol intake following AED consumption. AED users may underestimate their intoxication because they feel more stimulated, and subsequently believe they can drink more alcohol and/or stay out later. Alternatively, EDs may increase the reinforcing, positive effects of alcohol, strengthening AED consumers’ motivation to drink more alcohol. Finally, the taste of EDs may mask alcohol’s flavour, making alcohol consumption more palatable. While self-reported AED motivations generally support these explanations, there has been no objective research assessing whether these factors result in objective increases in alcohol intake.

## **2.10 Side-effects of AED Use**

The bulk of the AED literature published to date has been directed towards understanding the negative consequences or side-effects that occur either during or after the consumption of AEDs. The primary concerns raised by researchers and health professionals regarding AED use relate to the physiological and psychological side-effects of use and the potential for increased risk-taking during/post-AED consumption. The following sections will assess the validity of these concerns by examining the available survey and experimental research.

### ***2.10.1 Physiological and Psychological Side-effects of AEDs***

It is important to note that, although the data is limited because it is not collected routinely or in all countries and states, poison centre calls and emergency department presentations relating to EDs appear to have increased over the past decade. As discussed in Section 4.2, retrospective analysis of New South Wales poison’s data between 2004 and 2010 found 297 calls related to EDs, with calls increasing from 12 in 2004 to 65 in 2010. Sixty percent of calls were received between 5pm and 3am, and of those who had accidentally overdosed on caffeine as part of recreational consumption (n=217), 23% had co-ingested alcohol and 7% had ingested other stimulants (109). As aforementioned, ED presentations to US emergency departments doubled between 2007 and 2011. Over this time, the majority of energy drink-related ED visits involved either adverse reactions (67.6% of presentations in 2011)<sup>5</sup> or misuse or abuse of drugs (29.3% in 2011)<sup>6</sup>. In 2011, approximately 58% of presentations

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<sup>5</sup> An ED visit is categorised as an adverse reaction when the chart documents that a prescription or over-the-counter pharmaceutical, taken as prescribed or directed, produced an adverse drug reaction, side effect, drug-drug interaction, or drug-

involved energy drinks only, with 13% involving alcohol, and the rest involving other types of drugs (118). Over a five year period between 2004 and 2009, approximately 50% of admissions involving people between 18 and 25 involved the co-consumption of alcohol or other drugs (167). It is important to consider that poison centre calls and emergency department presentations may have increased in proportion to the popularity of these drinks; more research is needed to investigate this potential association.

To our current knowledge, only two studies have objectively measured the negative physiological side-effects of AED consumption. Ferreira et al. (158) found that there was no significant difference in heart rate or blood pressure following ingestion of alcohol (1.0g/kg) with or without 3.57mL/kg Red Bull®. However, it should be noted that maximal and ventilatory threshold heart rate was measured as opposed to resting heart rate. In contrast, Wiklund et al. (100) found that consumption of 750mL ED with alcohol lead to delayed recovery of heart rate and heart rate variability following a maximal bicycle ergometer exercise compared to a control condition were participants did not ingest any beverage. However, the absence of a placebo-matched condition means that AED expectancy effects cannot be ruled out. Furthermore, the absence of an alcohol comparison condition means that we cannot draw any conclusions regarding the relative effects of alcohol versus AED on heart rate and heart rate variability. While it should be noted that no participants in the study experienced clinically significant heart arrhythmias, the dearth of research objectively assessing the physiological outcomes of AED and alcohol consumption highlights the need for further research in this area, particularly outside of an aerobic performance-based context.

Negative consequences from AED use are commonly reported among young consumers. For example, in a web-based survey conducted by BAChe and Stockwell (122, 125), 46% of Canadian university students who had consumed an AED in the past month reported experiencing negative physical symptoms after combining alcohol and EDs. Primary side-effects included dehydration (72%), hangover (58%) and vomiting (35%). In a survey of ED users in Brazil conducted by Ferreira et al. (134), common negative effects included reduced inhibition (27%) and insomnia (11%).

The most well designed study to investigate the consequences of AED use was conducted by Peacock et al. (129). Importantly, this study compared AED sessions against alcohol-only sessions to disentangle the side-effects specific to AEDs. This study found that consumers reported significantly higher odds of experiencing difficulty sleeping, heart palpitations, tremors, jolt and crash episodes, increased speed of speech, and agitation in AED drinking sessions relative to alcohol drinking sessions. However, consumers also had significantly reduced odds of experiencing walking and vision difficulties, nausea, and slurred speech in AED sessions relative to alcohol drinking sessions.

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alcohol interaction. Although energy drinks are not treated as drugs by the Food and Drug Administration, ED visits involving energy drinks were classified as adverse reactions if the chart documented them as such. If other substances are reported on the chart as involved in the visit, an energy drink is not necessarily the sole reason for the adverse reaction (103).

<sup>6</sup> Misuse or abuse cases within DAWN are broadly defined to include all visits associated with illicit drugs, alcohol use in combination with other drugs, alcohol use only among those younger than 21 years old, and nonmedical use of pharmaceuticals (103).

Qualitative research conducted by Pennay and Lubman (132, 135) found that the most common negative effects of AEDs as self-reported by 10 young consumers were difficulty sleeping, worse hangovers the next day (self-reported as relative to alcohol-only sessions) and increased heart rate and palpitations, sometimes leading to feelings of anxiety (most notably the day after consuming these drinks). Qualitative research by Jones and Barrie (168) found that young consumers in Wollongong experienced heart palpitations, difficulty sleeping and worse hangover (self-reported as relative to alcohol-only sessions). Less commonly reported outcomes included aggression and twitching. It should be noted that this is the only study that has found self-reported increased aggression in association with AED consumption.

Table 7 shows the most commonly reported side-effects from AED use according to the available self-reported data.

*Table 7. Self-reported side-effects experienced from AED use in order of frequency*

Side-effects	% (showing the maximum cited across the articles)
(1) Dehydration	71
(2) Hangover	69
(3) Nausea/vomiting/gastrointestinal upset	35
(4) Difficulty sleeping	34
(5) Increased heart rate and palpitations	27
(6) Reduced inhibition (leading to regrettable incidents)	27
(7) Tremors	22
(8) Jolt and crash episode	22
(9) Agitation/irritability	19
(10) Aggression	-
(11) Twitching	-

\*The final two motivations were based on qualitative research with no percentages offered.

The main side-effects of AEDs as identified above include dehydration and hangover, which is not surprising given that alcohol and EDs are both diuretics. This might pose an additional health concern when AEDs are consumed in heated, crowded spaces, while dancing energetically (14). Increased dehydration may partially explain perceptions of a more severe hangover after consuming AEDs. While alcohol consumption is causally related to hangover independent of EDs, consumers in a number of studies have reported more severe hangovers after consuming AEDs than alcohol alone (58, 121, 125, 132). However, one recent study among Dutch university students conducted by Penning et al. (165) found no differences in relation to hangover between those who consumed

alcohol alone, alcohol with EDs, and alcohol with cola<sup>7</sup>. It is important to note that given the design of these studies (self-report), alcohol consumption is not controlled for, and perceptions of more severe hangover may be related to higher alcohol consumption during AED sessions (rather than the side-effects of AEDs). For example, the Dutch study that found AED users did not consume more alcohol than those in the alcohol-only group (165) also showed no difference in hangover severity.

Common physical consequences reported by consumers of AED include nausea, vomiting, gastrointestinal upset, heart palpitations and tremors. It is difficult to disentangle the effects of these physical consequences from alcohol only sessions, and again, these symptoms might be partially explained as a consequence of EDs potentially facilitating increased alcohol consumption (though it is important to note this relationship is unclear). However, Peacock et al. (129) found that AED users were six times more likely to experience heart palpitations in AED sessions than alcohol only sessions. This study found that odds of tremors and general psychomotor agitation were also higher during AED sessions.

Sleep difficulty is also commonly reported as a negative consequence of AEDs, presumably because of the stimulant properties of caffeine. Peacock et al. (129) found that after AED sessions, participants were four times more likely to experience sleep difficulties relative to alcohol only sessions. Pennay and Lubman's research (132, 135) revealed that after consuming AEDs it was common for AED users to fall asleep when they arrived home from a licensed venue, but then wake up after a number of hours and not be able to fall back sleep. The authors hypothesised that it may be that heavy alcohol intake promotes sleep induction, but the stimulant effects of caffeine take over as the alcohol is metabolised. Participants in this study reported that their routine was disturbed several days after the use of AEDs due to these sleeping difficulties (58, 132).

Palpitations and increased heart rate are self-reported by some AED consumers, but not all. From a cardiac perspective, there are three main concerns associated with excessive caffeine consumption: an increase in heart rate, an increase in blood pressure, and less commonly, increasing blood viscosity that can lead to blood clotting (169, 170). At least three independent cases have been described in the medical literature where consumption of EDs led to cardiac rhythm disturbances and cardiac arrest (171). These occur most often in those who are predisposed to arrhythmias because of underlying heart disease, and often are unaware of their underlying heart condition. Given that many young adults combine EDs with alcohol or physical activity, this further leads to concerns about heart problems (18). However, there is no evidence to suggest that alcohol exacerbates heart problems caused by caffeine.

Only one study, conducted by Pennay and Lubman (132, 135), has explored the perceptions of 'key stakeholders', including emergency services personnel, in relation to AED use and harm. A Melbourne paramedic reported witnessing many young people negatively affected by AEDs at music festivals and in the central business district area on weekends. He reported their usual symptoms as hypertension, nausea, high blood pressure, increased heart rate and palpitations. A harm reduction

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<sup>7</sup> One of the authors of this study has received research funding from, and has acted as a scientific advisor for, Red Bull GmbH.

officer who works at music festivals reported increasing presentations of alcohol poisoning in people who combine alcohol with illicit stimulants or EDs. A health worker expressed concern over clients with mental health problems, whose anxiety was presumed to be exacerbated by EDs and AEDs (132).

It is important to note that while rare, deaths following from the consumption of EDs (both in combination with alcohol and without alcohol) have occurred. In 2011 a 16 year old Australian girl died after consuming four cans of pre-mixed AEDs (Pulse) in the space of two hours. The cause of death was listed as undetermined, but the pathologist noted fluid on the lungs, which can be caused by heart failure (2). In 2000, an inquest was held into the death of an 18 year old male student in Ireland, who died while participating in a basketball tournament. He had been seen drinking three cans of EDs during the tournament. In 2001, three people died in Sweden, two after mixing EDs with vodka and the third after drinking several cans of EDs following a workout in a gym (38). All of these deaths have been attributed to heart failure but none can be said to be categorically caused by EDs or AEDs.

While there has been one study assessing whether ED consumers are at a higher risk of alcohol dependence (see Section 8), there has been, to our current knowledge, no research examining dependence and tolerance to AED or the effects of chronic use. This dearth of research may be attributable to AED use being a relatively new consumption trend. However, further research assessing the long-term effects of regular ED use is warranted, particularly in light of the aforementioned self-reported short-term side-effects.

In summary, the primary self-reported harms caused by AEDs include: a) dehydration and severe hangover; b) difficulty sleeping; and c) physiological impairment such as increased heart rate, palpitations, gastrointestinal upset, vomiting and nausea. Other symptoms such as agitation, irritability and aggression are less commonly reported. It is important to note with both b) and c) above, that it is unclear whether these effects are simply from excessive caffeine intake and whether co-consumption of alcohol contributes meaningfully to these symptoms. Further, the research reviewed in this section is based on self-report and no research has been conducted in controlled environments to investigate the effects of AEDs on dehydration, hangover, sleeping and other physiological problems such as gastrointestinal upset, with only a few studies examining heart rate and blood pressure, and only within an exercise context. Additionally, there has been no research assessing the long-term effects of AED use, particularly in relation to tolerance and dependence. More work is clearly needed in this area.

### ***2.10.2 Do AEDs Increase Risk-Taking?***

Several researchers have stated that underestimation of intoxication and increased alcohol intake following AED consumption may result in increased risk-taking (161). Accurate perception of intoxication is necessary for risk assessment, as consumers may underestimate how impaired their cognitive and motor skills are following AED consumption (126). Those studies comparing risk-taking behaviour in AED sessions versus alcohol sessions have generally revealed mixed results regarding

the relationship between AED use and risk-taking. A study of 150 American university athletes, conducted by Woolsey (124), revealed that AED users' had higher expectations of engaging in risk-taking behaviour in AED drinking sessions relative to alcohol drinking sessions. Examination of specific behaviours revealed that these consumers had significantly higher expectations of driving while intoxicated and engaging in aggressive behaviour while consuming AED, but there was no significant difference between AED and alcohol drinking sessions in regards to expectation of 'taking risks', 'enjoying sex more', 'being more likely to fight', and 'being brave and daring'. In contrast, 403 AED consumers in Peacock et al.'s (129) Australian community sample had significantly lower odds of engaging in 26 risk behaviours when they were consuming AED consumption relative to alcohol in the preceding six months. These risk behaviours included: driving practices, sexual practices, financial risk-taking, antisocial acts, licit and illicit drug use, and physical and mental physical harm, injury, and distress.

Despite these mixed findings, there has been no objective measurement of risk-taking following AED ingestion. Self-reported risk behaviour should be considered cautiously, as the sensitive nature of the items may increase response bias. While laboratory-based assessment of risk-taking may have reduced ecological validity, the controlled environment allows for direct assessment of AED's impact on risk-taking. Thus, it is important that survey research is supported by experimental research.

In summary, there are mixed findings regarding the relationship between AED consumption and risk-taking. While an American university student sample indicated higher expectations of risk-taking in AED sessions relative to alcohol sessions, an Australian community sample reported less engagement in risk-taking behaviour in AED sessions. Objective measurement of risk-taking in a laboratory setting could clarify whether AED consumption results in increased risk behaviour. This is an area where more research is needed.

## **2.11 Current International ED and AED Policy**

Issues relating to the production, supply, regulation and marketing of EDs and AEDs vary across countries, with Australia having some of the strictest regulations in relation to EDs. In the US there are no restrictions on the amount of caffeine in EDs and no requirement to label caffeine content on ED packaging. In a very recent move, a group of medical experts and prominent researchers in the US have written to the US Food and Drug Administration (FDA) in concern that there is insufficient evidence of the safety of EDs and urging them to legislate on levels of caffeine permitted in EDs and to impose a requirement that caffeine content be displayed on labels.

In relation to AEDs, in 2009 the FDA conducted a review and concluded that caffeine is an unsafe additive to alcohol. Nineteen states (Alabama, Georgia, New Jersey, Washington, Illinois, California, Iowa, Oklahoma, South Carolina, Vermont, Hawaii, Virginia, Rhode Island, Tennessee, New York, South Dakota, Texas, Maryland, and Pennsylvania) introduced legislation in 2010 banning pre-mixed AEDs from being produced, distributed, or sold in those states, and since this time some companies have removed the caffeine from their alcohol products (172). Over time pre-mixed AEDs have been prohibited in more US states. It is important to note this has only stopped the sale of pre-mixed

products that had been sold primarily at liquor and convenience stores. In bars and nightclubs, patrons are able to order alcohol mixed onsite with EDs (164). In Mexico, the sale of AEDs in all bars and nightclubs has recently been prohibited (173), though the degree to which this is monitored and enforced is unclear.

In Canada, legislation dictates that caffeine can only be mixed with alcohol if it comes from a natural source (e.g., coffee, cacao, guaraná but not vitamins or amino acids). In 2011 Health Canada reclassified EDs from a natural health product to a food to be regulated under the Food and Drugs Act. The reclassification has facilitated greater regulatory oversight at a federal level, including placing limits on the amount of caffeine in EDs (EDs can now contain no more than 400mg of caffeine per litre or 180mg per single serve; it should be noted that this is higher than Australian regulations), and requiring that the following warning labels are placed on the packaging of EDs: 'do not mix with alcohol', 'high source of caffeine', and 'not recommended for children, pregnant/breastfeeding women, individuals sensitive to caffeine' (this last statement is included on the cans of most EDs). Pre-mixed AEDs are also regulated under the Food and Drugs Act; however, because they are sold as alcoholic beverages they are only required to list the alcohol content on product labels. As part of this reclassification, Health Canada also now requires energy drink companies to submit annual data on sales, consumption and adverse events in relation to energy drinks (122, 173).

Also in Canada, various provinces have adopted regulatory approaches to AEDs. In 2009, the Liquor Control Board of Ontario undertook an independent review of AEDs and imposed a cap of 30mg of caffeine per serving on all products containing alcohol sold in Ontario. Over time other liquor authorities followed, with producers of pre-mixed AEDs reformulating their products to reduce the amount of caffeine (122).

In Europe there are a range of regulations that exist around EDs, varying by country; however, no such regulations exist around AEDs (173). In relation to EDs, current European legislation rules that beverages containing upward of 150 mg/L (other than tea or coffee) must be marked as 'high caffeine content' and that this statement should be in the same field of vision as the product name (173). Some countries have prohibited the sale of EDs in the past (including France and Denmark); however, these bans have recently been revoked. Norway restricts the sale of EDs only to pharmacies (16).

## **2.12 Current National ED and AED Policy**

The Australia New Zealand Food Standards Code (15) specifies that EDs may contain a maximum of 320mg/L caffeine, or 80mg per 250mL standard ED. Similar restrictions exist for the amount of taurine and glucuronolactone permitted in EDs. However, aside from this, there are no regulations on the supply, sale, and marketing of EDs or AEDs in Australia except for in Western Australia. In 2009, the Western Australian Department of Racing, Gaming and Liquor developed a condition that is placed on some licences prohibiting the sale of liquor mixed with EDs. This condition is applied to the majority of one-off events, the majority of extended hours permits for long weekends, the majority of applications for ongoing hours Extended Trading Permits, and new licence applications on a case by case basis.

In May 2011, the condition was placed on all late-night licensed hotels, taverns, small bars and some special facility venues in the inner city entertainment precinct of Perth. It is now prohibited to sell liquor mixed with EDs after midnight in these venues. However, EDs and alcoholic drinks can still be purchased separately, meaning that patrons can potentially hand-mix these products themselves or continue consuming EDs and alcohol in the same session, which is likely to undermine the intention of this policy.

Research shows that Australians in general are amenable to stricter policies on AEDs. A recent population survey among 1009 Australians showed that 75% do not think alcohol should be mixed with EDs and 59% support a ban on pre-mixed AEDs. The demographics most likely to support the ban on pre-mixed AEDs were people between 13 and 17 years, people aged between 47 and 65 years, non-drinkers and low income earners. People aged 18 and 30 years were least likely to support a ban on pre-mixed AEDs (174).

A recent qualitative survey that involved two interviews with Victorian Department of Health employees reported their view that there is currently insufficient evidence regarding the harms of AEDs to make regulatory changes at the state level. One policy maker stated that they cannot prohibit the manufacture of pre-mixed AEDs because the Food Standards Code is written in such a way that their combination is permitted and this cannot be changed without evidence showing AEDs are causing significant harm over that of alcohol alone (132).

When considering the potential regulation of AEDs in Australia in the future, it is important to consider two points. First, research from the alcohol field has consistently found that controls on the physical availability of alcohol and the cost of alcohol are most effective for reducing consumption and alcohol-related harms, while measures such as education, media campaigns and warning labels show less evidence of effectiveness (122, 175). Bearing this in mind, it is reasonable to infer that restrictions on the production of AEDs (including beverage ingredients and limits), the sale of AEDs (including banning their sale altogether or during particular hours, at particular venues or in a particular form) and increasing the cost of AEDs are likely to have the most impact on the extent to which they are purchased and consumed. It is also important to consider that most of the focus on legislation has been centred around controlling the production and sale of pre-mixed AED; however, such policies are undermined by the ability to 'mix your own' at home or in social settings (173), and it is worth noting that the limited research conducted so far shows that pre-mixed AEDs are much less popular than 'mix your own' AEDs, so policy interventions to prohibit the sale of the pre-mixed products may have limited effects on rates of AED use in the population (176). In addition, pre-mixed AEDs often have a lower caffeine content (average 21mg per 300mL as opposed to 80mg per 250mL in Red Bull®), meaning that 'mix your own' AEDs are potentially more dangerous. It is important to consider the implication that removing the sale of pre-mixed AEDs (relatively safer products with regulated low caffeine levels) could lead consumers to shift to hand-mixed AEDs which might involve more risk (122).

A second important point to consider in regards to regulation is that the current research literature, as reviewed in this document, does not show compelling evidence that AEDs are associated with

significant side-effects above caffeine or alcohol alone. While ED and AED presentations are increasing to US emergency departments, these presentations may have simply increased in proportion to the popularity of these drinks. In addition, very few serious or life-threatening consequences of ED or AED consumption have been reported. Furthermore, as outlined in this review, the link between AED use and increased alcohol consumption and risk-taking is unclear. More research needs to be undertaken to inform potential regulatory approaches.

### **2.13 What Future Research is Needed?**

This literature review highlights a number of gaps in relation to AED use in Australia. In Australia we do not know the prevalence of AED use in general population samples, how rates of use differ between states, how rates of use vary between metropolitan, regional and rural areas, and how popular AEDs are among selected sub-groups such as students or young people. We also do not have a good understanding of the socio-demographics of AED users. The most effective ways to collect this data regularly would be to add questions about the consumption of EDs and AEDs to existing national surveys such as the National Drug Strategy Household Survey, state-based surveys such as the Victorian Youth Alcohol and Drugs Survey, and secondary school surveys such as the Australian School Students Alcohol and Drug Survey. To complement this data it is also important to access sales data on both EDs and pre-mixed AEDs. While sales data will not necessarily reflect the popularity of hand mixed AEDs, it will provide some insight as to the popularity of EDs and AEDs in Australia.

While it is important to understand how widely AEDs are used among the general population, population-based methodologies under-sample the demographic most likely to consume AEDs (i.e., people aged 16-30). For example, random-digit dialling approaches often neglect the mobile-phone only population and are subject to further biases such as over-representing those who are unemployed, engaged in home duties or retired. Therefore, such strategies should be complemented by further targeted survey research, such as surveys in Australian university populations, secondary school populations and targeted community samples, to complement the one Australian study so far conducted by Peacock et al. (128, 129) which was comprised of mostly Tasmanian residents.

Further qualitative research is required to explore the ways in which young people consume AEDs and the social and cultural contexts of AED use. Research should be conducted amongst diverse samples, including various sub-groups of AED users. For example, those that consume a moderate number of AEDs per session and those that consume over eight AEDs per session. Some young people are also consuming AEDs while concurrently using illicit drugs. Future research should attempt to gather more detailed information across these different consumption patterns. Research is also lacking on populations under the age of 18 years, and these people are likely still in a period of experimentation with alcohol and AEDs. Young people might be more likely to experience acute harms from the consumption of AEDs (through over-consumption) and be most susceptible to the marketing and advertising of these products (58, 132).

Given that AEDs are commonly consumed in licensed venues, research is needed to understand the role that AEDs plays for venue workers, security staff and police; for example, whether the combination increases alcohol-related intoxication and/or related aggression or violence. In addition, given that participants report harms such as increased heart rate, heart palpitations, gastrointestinal upset, nausea, shakiness and twitching, research is needed into the implications of AED use for emergency services personnel (including paramedics and hospital staff), as well as other health workers (58, 132). Such research will provide information on what is happening to AED consumers at the severe end. Qualitative methods such as observational research and in-depth interviews are likely to be useful for this research, as well as secondary analysis of ambulance, hospital and police data to quantify the harms caused by AEDs. However, at present, AEDs use is not routinely collected by emergency services staff and police, so an important first step is to make changes to the coding process and collection of AED-related information, particularly in relation to ambulance presentations, to enable the review and analysis of these records.

While the links between AED use and increases in intoxication and harm should not be taken lightly, it is important to stay mindful of the impact of expectancy effects or sampling bias. ED marketing is targeted towards young consumers and implies that these drinks induce an intense psychoactive effect. Therefore, people who consume AEDs might be those who are already motivated to drink heavily and to intoxication (173). In addition, the extent to which study findings, such as increased alcohol intoxication or more negative consequences among AED users, are due to the properties of caffeine, or other additives or a synergistic pharmacological relationship, and whether they are mediated by expectancy effects, are unclear (173). For example, while taurine and glucuronolactone are not necessarily harmful when consumed alone, there is insufficient data regarding their potential interactive effects with one another, or with caffeine, guaraná and alcohol (14). In addition, a fundamental question that has not been adequately addressed is whether or not the relationship between AEDs and behavioural consequences is confounded by personality. For example, it may be that young people who have made the decision to party hard deliberately select these beverages to facilitate their intentions, therefore creating a selection bias (176). Or it may be that high sensation seeking or impulsive individuals are drawn to heavy alcohol consumption, EDs, drug use and risky behaviours in general (125). Future research should attempt to unpack the relationship between EDs and increased alcohol consumption and risk-taking. This might include experimental research objectively measuring risk-taking behaviour following ED consumption.

ED side-effects have been identified via case reports and emergency centre and poisons information centre data, and inferred from caffeine research. There is a dearth of research directly objectively assessing the safety of the 'whole' beverage. Further research is required specifically measuring the frequency of side-effects and the ED doses at which they are likely to appear. Furthermore, the 'actual' harms associated with AED are still somewhat of a mystery. While young people report adverse effects such as sleep difficulty, severe hangover and racing heart, it is unknown at what quantities these problems occur, whether they occur in all consumers, whether they occur with all types of alcohol, and whether they are specific to EDs (and may be a function of other ingredients such as taurine) or also a feature of caffeine in other sources (such as coffee and cola soft drinks). As

such, rigorous randomised controlled trials need to be conducted to investigate the physiological and psychological effects of AEDs on different groups of the population (such as caffeine naive people, polydrug users, etc.), at different alcohol and ED quantities and across different beverage types, such as different types of alcohol (such as beer and spirits) and different types of EDs (as ED beverages can differ in their ingredient composition and quantity according to product and national regulatory body guidelines). In particular, it is important to understand the dose-response relationship of AEDs and at what levels of alcohol and EDs harm rises appreciably (132). Furthermore, there has been no research assessing the long-term effects of AED use, particularly in relation to tolerance and dependence.

There has been considerable debate regarding the effect of AED use on objective intoxication, assessed via performance outcomes, and subjective intoxication, assessed via self-report. Generally, research has shown that AED and alcohol-only consumption result in similar deficits in objective performance outcomes. However, it must be noted that these findings have been established with set AED doses and little research has been conducted using dosing procedures which reflect real-life AED consumption quantities. For example, the majority of studies have involved administration of 250mL ED (80mg caffeine), despite survey research revealing that Australian AED consumers typically ingest 2.4 standard 250mL EDs per AED drinking session (128). Findings are mixed regarding AED consumers' perception of intoxication. While some studies have revealed similar ratings of intoxication following AED and alcohol consumption, two studies have reported higher ratings of stimulation following AED consumption. Despite these conflicting findings, several researchers have argued that AED consumption results in an underestimation of intoxication, whereby the feelings of increased stimulation reduce the sedative cues which indicate intoxication. Accurate assessment of intoxication is important, as reduced perception of intoxication may result in increased alcohol intake and a higher likelihood of engaging in risk-taking behaviours. However, there has been no objective measurement of risk-taking behaviour following AED consumption. As such, further research needs to be conducted assessing the impact of AEDs (administered at doses similar to those consumed in real-life) on: (i) objective measures of performance and risk-taking, and (ii) subjective measures of intoxication.

### 3. ANALYSIS OF SECONDARY DATA

#### 3.1 Introduction and Aims

As detailed in the literature review, most of the harms reported in relation to AEDs are self-reported by participants in surveys because there is very little data available on harms resulting from AEDs recorded through police, hospital, ambulance and coronial data. One of the reasons that this data is not more readily reported is because information on alcohol use, and particularly information on energy drinks, is often not well collected by emergency services. To our knowledge, the only published emergency services data on AED use is from The Drug Abuse Warning Network (DAWN), a public health surveillance system that monitors drug-related emergency department visits in the US, and the NSW State-wide Poisons Information Centre (NSWPIC); both show that harms resulting from AED use have increased over time, alongside the increasing popularity of use. As described in the literature review, the most recent DAWN report showed that between 2007 and 2011 visits to US emergency departments involving EDs doubled, from 10,068 to 20,783. Approximately 58% of presentations involved energy drinks only, with 13% involving alcohol, and the rest involving other types of drugs (118). Analysis of NSWPIC data between 2004 and 2010 was published in the Australian Medical Journal by Gunja and Brown (109). They reported that 297 calls related to energy drink exposure had been made during this time, with calls increasing from 12 in 2004 to 65 in 2010. Sixty percent of calls were received between 5pm and 3am, and of those who had accidentally overdosed on caffeine as part of recreational consumption ( $n=217$ ), 23% had co-ingested alcohol and 7% had ingested other stimulants.

To our knowledge, these are the only studies that report on harms arising from AED use at the severe end (i.e., that are likely to require medical treatment); however, very little contextual information about these presentations has been provided in the published reports. It is the purpose of this report to analyse data from NSWPIC and NSW emergency departments to identify more detailed information about AED presentations in NSW.

#### 3.2 Poisons Data

##### 3.2.1 Methods

A retrospective review of calls to the NSW State-wide Poisons Information Centre (NSWPIC) from 1<sup>st</sup> January 2004 to 9<sup>th</sup> November 2012 was undertaken as an indicator of the harms associated with AED consumption. NSWPIC is a poison centre based in New South Wales which is open to calls 24 hours a day, 7 days per week; calls from New South Wales, the Australian Capital Territory and Tasmania are handled by NSWPIC exclusively from 6am to midnight and after-hours calls from all of Australia are shared between the four Australian Poisons Information Centres (PICs). Permission was provided by the data custodian for access to PICs data that was already held by NSW Health; additional ethics approval was not required.

Data comprised calls made from the general public and health professionals seeking advice for risk assessment, management and treatment following exposure to AEDs. Each record comprises clinical notes typed into the database at the time of the call by the Poisons Information Specialist who took the call; these notes summarise the phone call, they are not from recordings or transcripts. All substances used are entered in free-text and into pre-coded categories in the database by the call taker.

The data was prepared and cleaned by NSWPIC. The NSWPIC Microsoft Access database was searched using the following terms, including “guarana”, “caffeine”, “ethanol”, “food additives”, “energy drink”, “alcohol: other/unknown”, and “non-drug product: other/unknown”. Due to the large number of “other/unknown” exposures, a filter was applied to find results with the name of any known Australian marketed energy drink or “caffeine” or “energy” in the free-text product name field.

All the cases found from this search were subjected to manual review for inclusion and subsequent coding and verification of the reported type of exposure, co-ingestants, symptoms, dose, brand of drink, and the subject’s age, sex and hospitalisation status. Symptoms and coding were reviewed separately by the authors. Discrepancies were discussed until agreement was achieved. As part of the manual review for inclusion, both an energy drink product and alcohol needed to be stated in the call record as having been used. Only call origins of NSW were used, in the specified time period.

As noted above, the calls were categorised according to the type of exposure:

- ‘Recreational exposure’: intentional ingestion for the purpose of gaining euphoria or other psychotropic effects.
- ‘Accidental paediatric exposure’: non-deliberate ingestion by a person under 18 years of age.
- Deliberate self-poisoning: intentional ingestion as part of a polypharmacy overdose (109). These cases are distinguished from recreational exposure by identification of self-harm intent and are generally differ from recreational exposure in that they typically involve polypharmacy ingestions where other substances (e.g., antidepressants) are consumed in significant quantities.

Calls were also classified according to symptom status: (i) asymptomatic, (ii) symptoms related to AED use, and (iii) symptoms of an unknown relationship to AED use (i.e., there may be other explanations for the signs and symptoms exhibited). The relationship between symptoms and AED use was determined by clinical judgement of Poisons Information Specialists from existing evidence of known signs and symptoms, pharmacology and toxicity of the substances used.

Statistical analyses were conducted in SPSS Statistics version 19. Descriptive data were calculated for variables of interest.

### 3.2.2 Results

#### 3.2.2.1 General Overview of PIC Calls

Between 1 Jan 2004 and 9 Nov 2012, NSWPIC took 993,526 calls; of which 676,011 were unique exposure-related calls. Thirty-nine calls related to AED use were recorded during the nine-year observation period, representing less than 0.006% of all unique exposure-related calls. The majority of AED calls related to recreational exposure ( $n=32$ ), with five cases of accidental paediatric exposure and two cases of deliberate self-poisoning.

The annual number of calls according to exposure type is displayed in Figure 1. Call numbers were highest in 2008, with numbers remaining low over the nine year period.

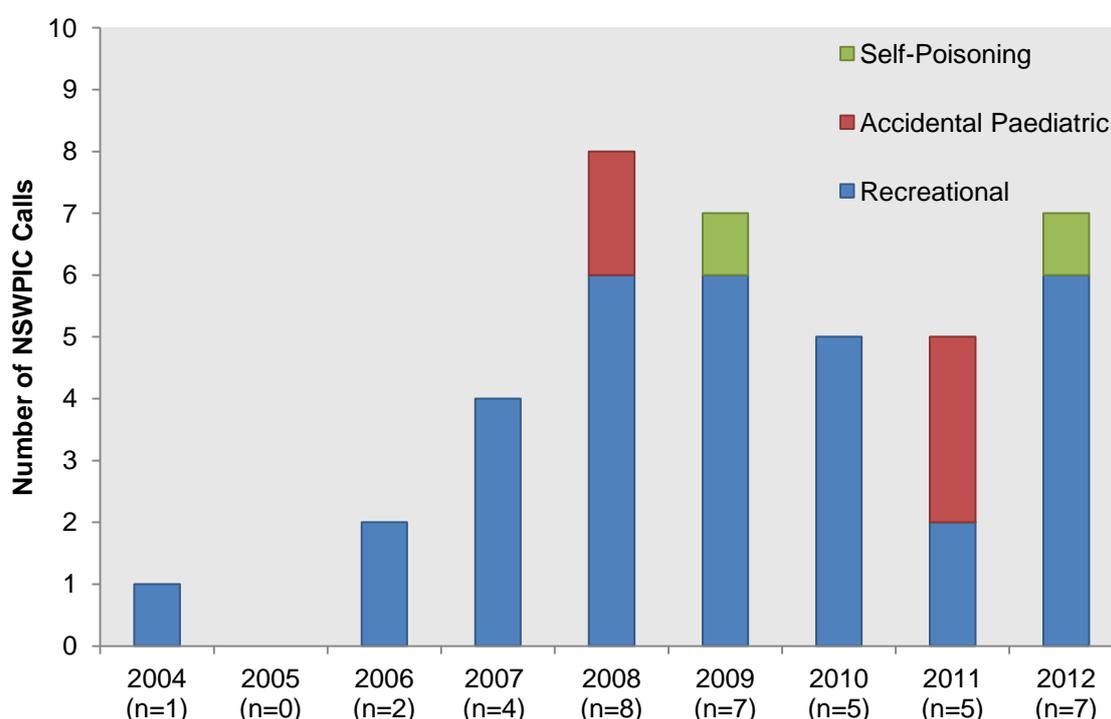


Figure 1. Annual number of NSWPIC calls according to exposure type ( $n=39$ )

Note: \* This is total amount of calls relating to AEDs, not a proportion of that year. It is important to note that the total number of calls to NSWPIC vary year to year.

Over half the calls (54%,  $n=21$ ) occurred in the early hours of the morning (12:01am to 9:00am) (see Figure 2). Almost one-quarter (23%,  $n=9$ ) of the calls occurred of an evening (i.e., 6:00pm to midnight). Only 15% ( $n=6$ ) of calls were made by the consumer themselves, with the majority of calls made by a doctor (26%,  $n=10$ ), family member (23%,  $n=9$ ), nurse (21%,  $n=8$ ), or friend (15%,  $n=6$ ).

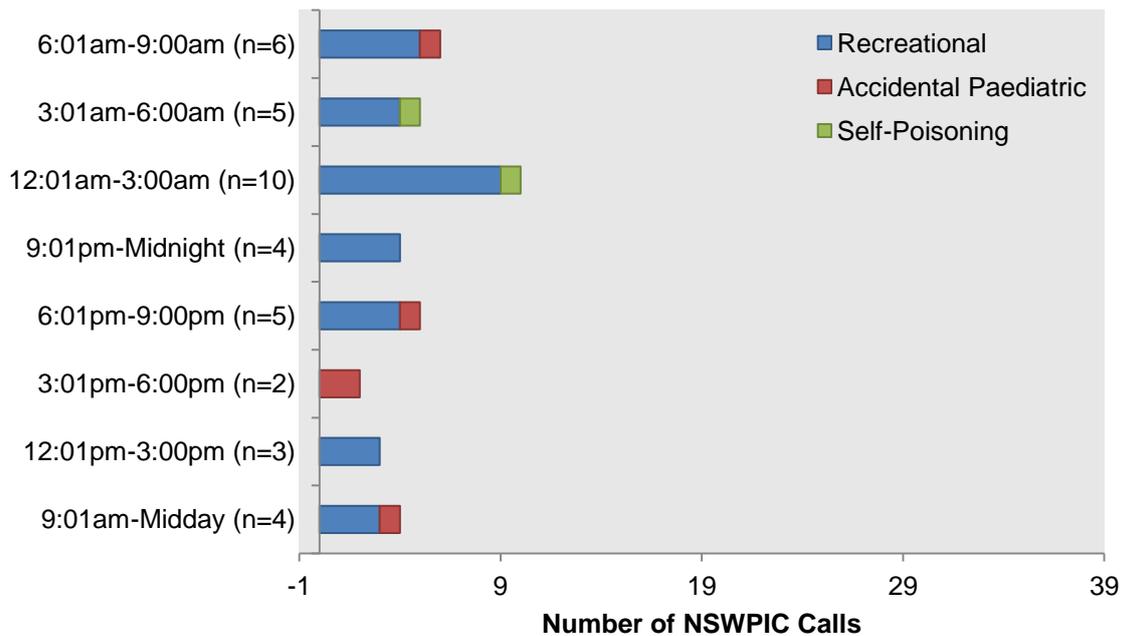


Figure 2. Number of NSWPIC calls according to time of day (n=39)

Two-fifths (39%, n=15) of the sample reported co-ingesting AED with other substances. Co-ingestion of AED with other substances occurred primarily during recreational exposure (93%, n=14), with the remaining case of co-ingestion occurring during deliberate self-poisoning. The types of substances co-ingested with AED are displayed in Table 8. Of those consumers who co-ingested AED with other substances:

- Two-fifths used illicit stimulant drugs (n=6)
- One-quarter used licit or illicit prescribed medication (n=5)
- One-fifth used other caffeine products (n=3)
- One-tenth used other illicit drugs (n=2)

Table 8. Number of exposures according to the type of co-ingested substance (n=14)

	Number of Calls
<b>Illicit Stimulant Drugs</b>	<b>6</b>
Ecstasy	5
Cocaine	2
Amphetamine	2
<b>Other Illicit Drugs</b>	<b>2</b>
LSD	1
Cannabis	1
<b>Prescribed Medication*</b>	<b>4</b>
Antidepressant	2
Benzodiazepine	1
Antipsychotic	1
Dexamphetamine	1
<b>Non-Prescribed Medication</b>	<b>1</b>
<b>Tobacco</b>	<b>1</b>
<b>Caffeine Products</b>	<b>3</b>
Caffeine tablets	1
Coffee	2

Note: \* Those calls regarding co-ingestion of prescribed drugs may refer to illicit and/or licit use.

### 3.2.2.2 Demographics and Exposure Characteristics

This section documents the demographic characteristics, types of exposure, and the symptomatic profile of the whole sample, as well as consumers who fall within the primary exposure subsamples: (i) recreational exposure (subdivided by those who co-ingested AEDs with other substances), and (ii) accidental paediatric exposure.

#### Whole Sample

- The number of male (46%,  $n=18$ ) and female (51%,  $n=20$ ) consumers in the overall sample was relatively even; the sex of one consumer (2%) was not assigned.
- The majority of consumers were adults (aged 20-74 years; 59%,  $n=23$ ); almost one-fifth (18%,  $n=7$ ) were adolescents (aged 15-19 years) and over one-tenth (13%,  $n=5$ ) were toddlers (aged 1-4 years); there were no exposures reported for infants (1 month to 11 months), children (5-14 years), or elderly (75 years or older) consumers. It should be noted that one-tenth (10%,  $n=4$ ) were not assigned to an age category. Actual age was only reported in 23 (59%) of the calls. Where it was, the mean age of adolescents was 16.3 years (range 16-17) and the mean age of adults was 24.5 years (range 18-60). All but one adult were under the age of 32.

- The majority of calls were in relation to hand-mixed AEDs (67%;  $n=26$ ), with premixed alcoholic energy drinks accounting for one-tenth (13%,  $n=5$ ) of calls and this information was unknown in 20% ( $n=8$ ) of calls.

### Recreational Exposure among AED-only ( $n=18$ ) and AED and Other Substances ( $n=14$ )

#### Subsamples

- Nearly three-fifths of the AED-only subsample were female, whereas there was an even split of males and females in the AED and other substances subsample (see Table 9).
- Half of the AED-only subsample were categorised as adults and one-fifth were categorised as adolescent. However, one-fifth did not provide sufficient data to be categorised. Nearly nine-tenths of the AED and other substances subsample was categorised as being adult.

*Table 9. Demographic and exposure characteristics of the AED-only recreational exposure subsample ( $n=18$ ) and AED and other substances recreational exposure subsample ( $n=14$ )*

	AED-only Recreational Exposure ( $n=18$ )	AED and other Substances Recreational Exposure ( $n=14$ )
Sex		
Male	7	7
Female	10	7
Unassigned	1	0
Age Category		
Toddler	0	0
Adolescent	4	2
Adult	10	12
Unassigned	4	0

### 3.2.2.3 Side-Effects of Exposure

#### Whole Sample

- Six of the consumers (15%) were reported as asymptomatic and one-fifth (5%,  $n=2$ ) had symptoms unrelated to AED use, while almost half (46%,  $n=18$ ) reported symptoms clinically related to AED use, and over one-third (33%,  $n=13$ ) had symptoms which were of an unknown relationship to AED use.
- As seen in Figure 3, the primary symptoms reported by those consumers who experienced symptoms directly related to AED use or of an unknown relationship ( $n=31$ ) included agitation, tremors, abnormally fast heartbeat, irregular heartbeat, nausea and vomiting.
- As evident in Figure 4 (over the page), over one-third (36%,  $n=14$ ) of the sample were referred to hospital by NSWPIC based on the clinical significance of their symptoms. Two-fifths (44%,  $n=17$ ) were at a hospital at the time of the call. One-fifth (21%,  $n=8$ ) were advised to stay at home following evaluation of symptoms.

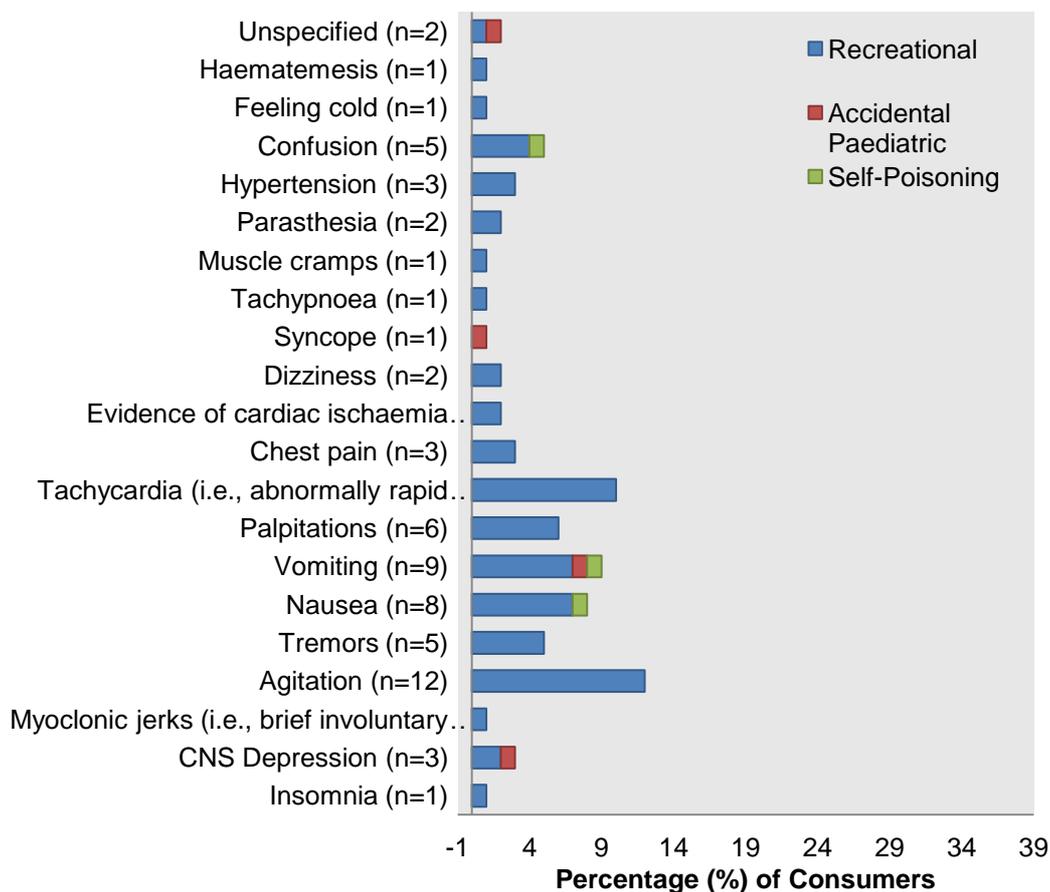


Figure 3. Number of consumers in the whole sample who reported experiencing symptoms caused by AED consumption or of an unknown relationship to AED consumption ( $n=31$ )<sup>8</sup>

<sup>8</sup> The symptoms are defined as: insomnia: inability to sleep; CNS depression: depression of the nervous system which can result in decreased rate of breathing, decreased heart rate and loss of consciousness; myoclonic jerks: brief involuntary twitches; tremors: involuntary quivering or trembling; palpitations: irregular heart rate; tachycardia: abnormally rapid heart rate;

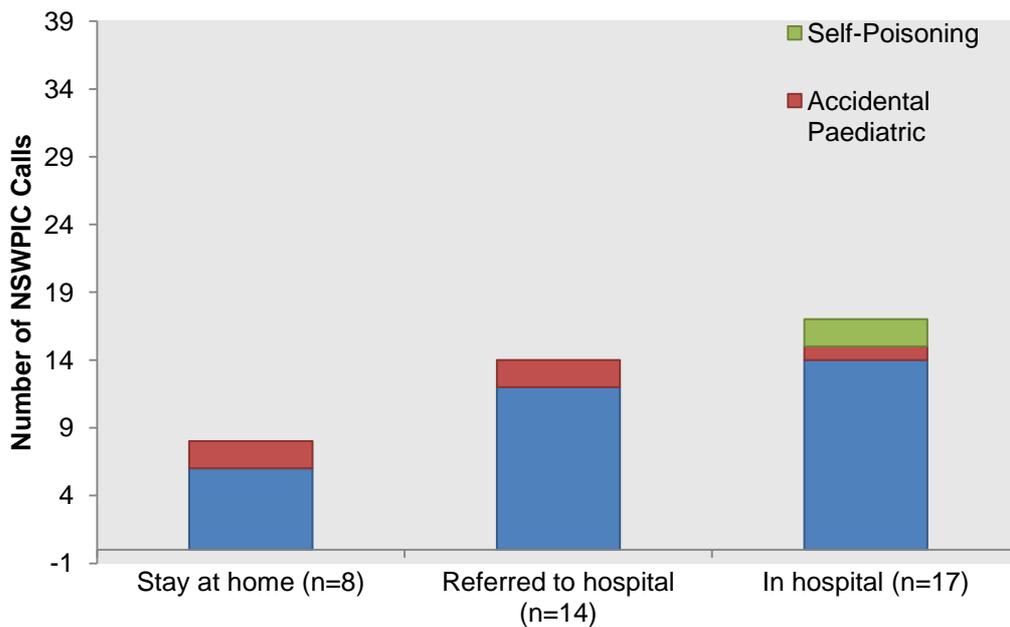


Figure 4. Handling of NSWPIC calls for the whole sample based on the clinical significance of symptoms (n=39)

### Recreational Exposure

- As evident in Figure 5, agitation, nausea, vomiting, tremors and irregular heart rate, and abnormally fast heart rate were the primary symptoms reported by AED-only recreational consumers whose symptoms were directly related or of an unknown relationship to AED use (n=17). Similar symptoms were observed among those who had consumed AEDs and other substances.
- As evident in Figure 6, the majority (n=8) of those who had consumed AEDs and other substances were in hospital at the time of the NSWPIC call, with just over one-third (n=5) referred to hospital. Approximately one-third (n=5) of AED-only recreational consumers were advised to stay home, one-third (n=7) were referred to hospital based on the clinical significance of their symptoms, and one-third (n=6) were in hospital at the time of the NSWPIC call.

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evidence of cardiac ischaemia: insufficient blood flow to the heart; syncope: partial or full temporary loss of consciousness due to fall in blood pressure; tachypnoea: rapid breathing; parasthesia: sensation of tingling, itching, or burning with no apparent cause; hypertension: abnormally high blood pressure; haematemesis: vomiting of blood.

Table 10. Number of recreational AED-only (n=18) and AED and other substance subsample (n=14) according to symptom status

	AED-only Recreational Consumers (n=18)	AED and other Substances Recreational Consumers (n=14)
Asymptomatic	1	1
Not related symptomatic	0	2
Not known if related	6	6
Related symptomatic	11	5

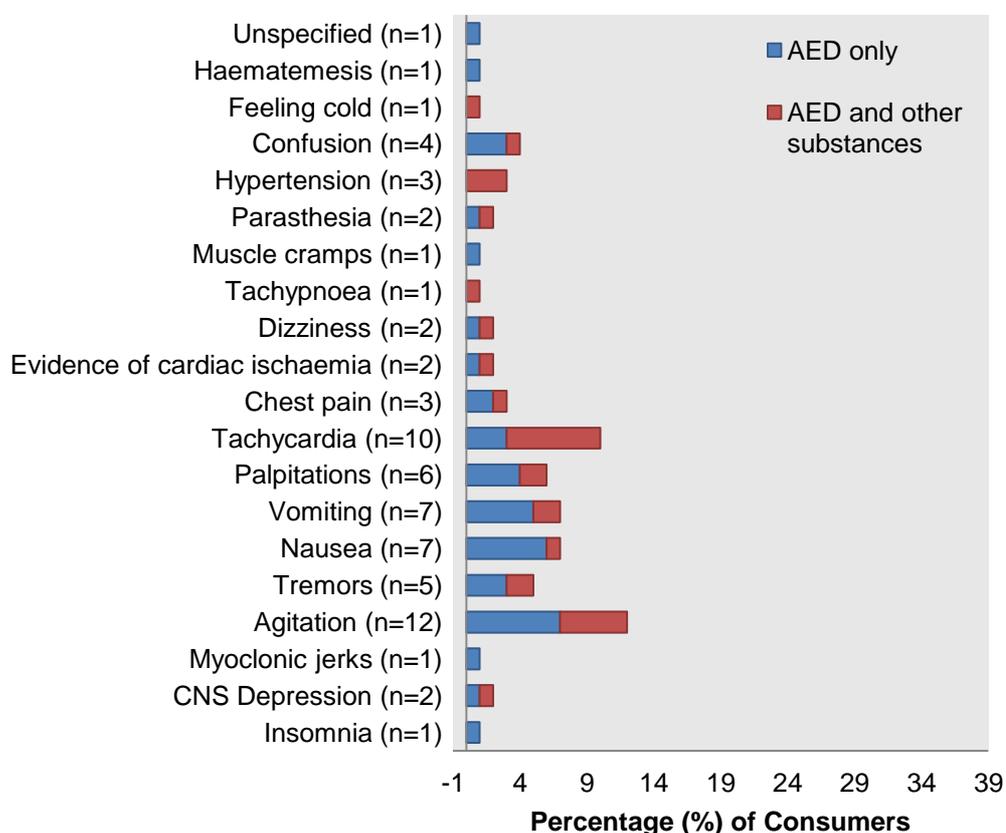


Figure 5. Number of AED-only (n=17) and AED and other substances (n=11) recreational consumers only who reported symptoms related to their AED use or of an unknown relationship to AED consumption<sup>9</sup>

<sup>9</sup> The symptoms are defined as: insomnia: inability to sleep; CNS depression: depression of the nervous system which can result in decreased rate of breathing, decreased heart rate and loss of consciousness; myoclonic jerks: brief involuntary twitches; tremors: involuntary quivering or trembling; palpitations: irregular heart rate; tachycardia: abnormally rapid heart rate; evidence of cardiac ischaemia: insufficient blood flow to the heart; tachypnoea: rapid breathing; parasthesia: sensation of tingling, itching, or burning with no apparent cause; hypertension: abnormally high blood pressure; haematemesis: vomiting of blood.

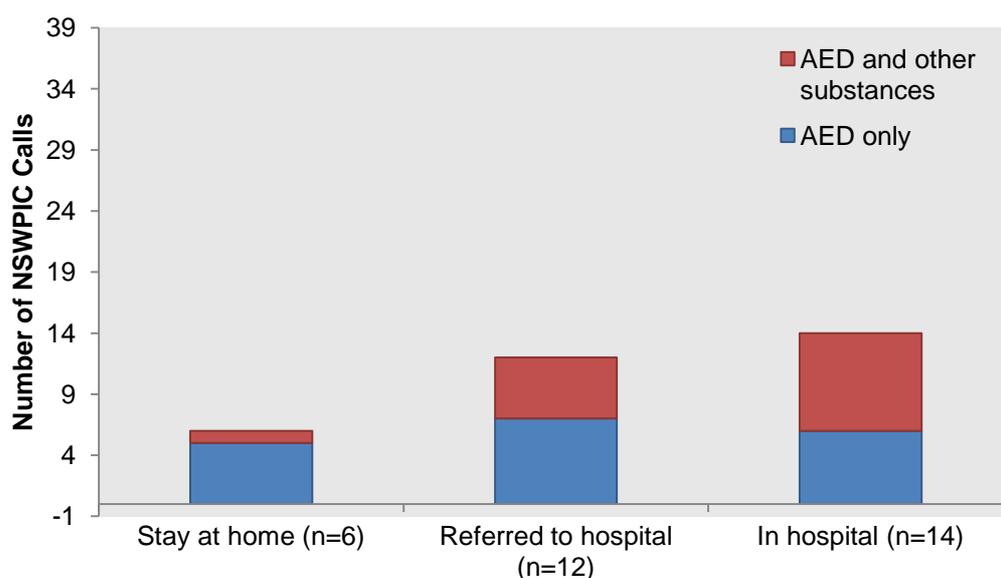


Figure 6. Handling of NSWPIC calls for AED-only recreational consumers (n=18) and AED and other substances recreational consumers (n=14)

### Accidental Paediatric Exposure

- Three accidental paediatric exposure consumers were asymptomatic, one consumer had symptoms which were clinically related to AED use and one consumer had symptoms of an unknown relationship to AED consumption.
- Symptoms experienced by the two latter consumers were CNS depression (i.e., depression of central nervous system indicated by slower heart rate, slowing breathing and even loss of consciousness) (n=1), vomiting (n=1), syncope (i.e., partial or full temporary loss of consciousness due to decrease in blood pressure) (n=1) and symptom unspecified (n=1).
- Of the accidental paediatric exposure sample, one consumer was in hospital at the time of the call, while two consumers were referred to hospital based on the clinical significance of their symptoms. Two consumers were advised to stay at home.

## 3.3 Emergency Department Data

### 3.3.1 Methods

A retrospective analysis of records from the emergency departments of 59 hospitals in New South Wales from 1<sup>st</sup> January 2007 to 30<sup>th</sup> November 2012 were undertaken as an indicator of serious harms associated with AED consumption. These 59 hospitals represent approximately 84% of NSW public hospital emergency department activity. The remaining 16% of public hospital emergency departments in NSW do not participate in the *near real-time ED surveillance system*. The near real-time system includes text recorded during triage nurse assessment on patient arrival and enables the use of complex keyword searches for very specific types of presentations. The 59 included

emergency departments comprise all hospitals in metropolitan Sydney, all large regional hospitals, and several smaller public hospital emergency departments in NSW.

Through preliminary exploration of emergency department data, it was determined that diagnosis codes would not be useful in quantifying the problem because energy drink and alcohol use may be incidental factors. Further, where alcohol and energy drink consumption may have been recorded using ICD codes, it is not possible to accurately identify such cases, as the same ICD code is used for both caffeine toxicity and amphetamine toxicity. In order to extract information regarding alcohol and energy drink involvement in emergency department presentations, a search of patient records was undertaken. Records were included if the text recorded by triage nurses on the emergency department patient management information systems contained information related to recent alcohol and energy drink consumption. The search keywords used for alcohol consumption included: "jager", "bomb", "alcohol", "etoh", "vodka", and "intox". The keywords used for energy drink consumption included: "taurin", "Rockstar", "Pure Energy", "Monster", "Cintron", "Fuel Cell", "Smart Energy", "Bad Boy", "Endorush", "Uzi", "Red Bull", "Raging Rex", "Guarana", "energy drink", "energy shot", and "caffeine". The records were manually reviewed to exclude irrelevant (false positive) presentations, including non-energy drink caffeine presentations and those describing only past use of energy drinks and alcohol. It was not practically possible to include the names of several other prominent energy drink brands in Australia (i.e., V®, Red Eye®, and Mother®) due to previous searches yielding a large number of false positive returns. As such, it should be noted that there may be some bias in the results towards those specifically named brands identified in the search.

The data searching and analysis was undertaken by staff at the NSW Emergency Department and Ambulance Surveillance System, Centre for Epidemiology and Evidence, NSW Ministry of Health. Aggregated data were provided for the purpose of this report.

### **3.3.2 Results**

From 1<sup>st</sup> January 2007 to 30<sup>th</sup> November 2012, there were 657 AED-related presentations (of 10,535,694 total presentations) identified from a database of all emergency department presentations to 59 NSW public hospitals. These numbers increased sharply from 2007 to 2009 but have remained relatively stable since that time, with around 120-140 presentations per year (see Figure 7). There have been an equivalent number of males (52.7%;  $n=346$ ) and females (47.3%;  $n=311$ ) presenting to the emergency department relating to AEDs.

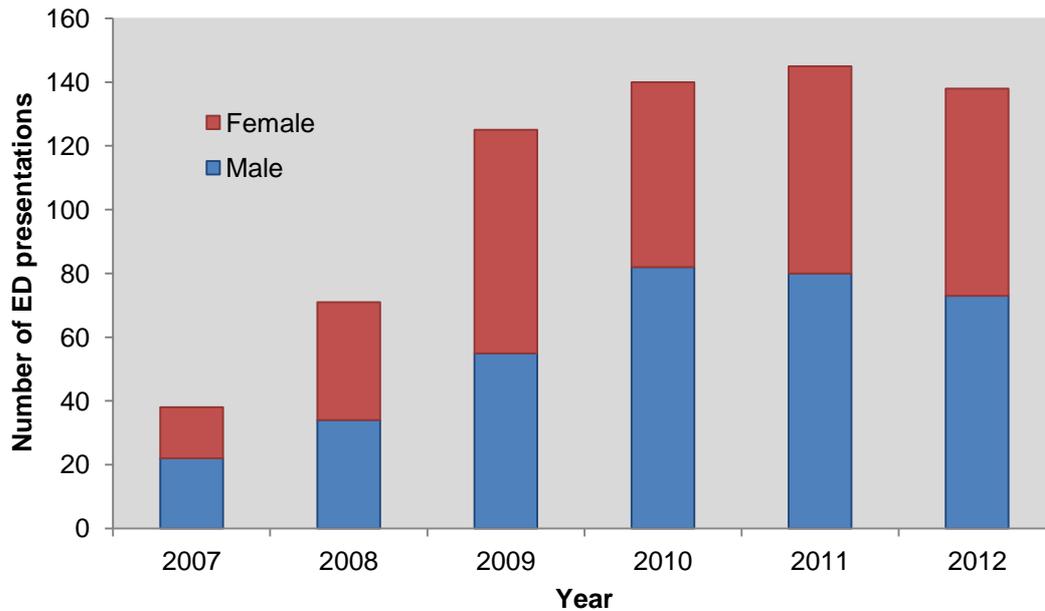


Figure 7. Number of emergency department presentations mentioning recent alcohol and energy drink consumption, by year and sex

\*2012 data is from January 1<sup>st</sup> to November 30<sup>th</sup>

The majority of presentations to emergency departments as a result of AED consumption involved young people; specifically, 84% ( $n=557$ ) of presentations involved people aged 15-29 (see Figure 8). Almost one third (32%;  $n=209$ ) of those presenting to an emergency department as a result of AED use were between the ages of 15-19.

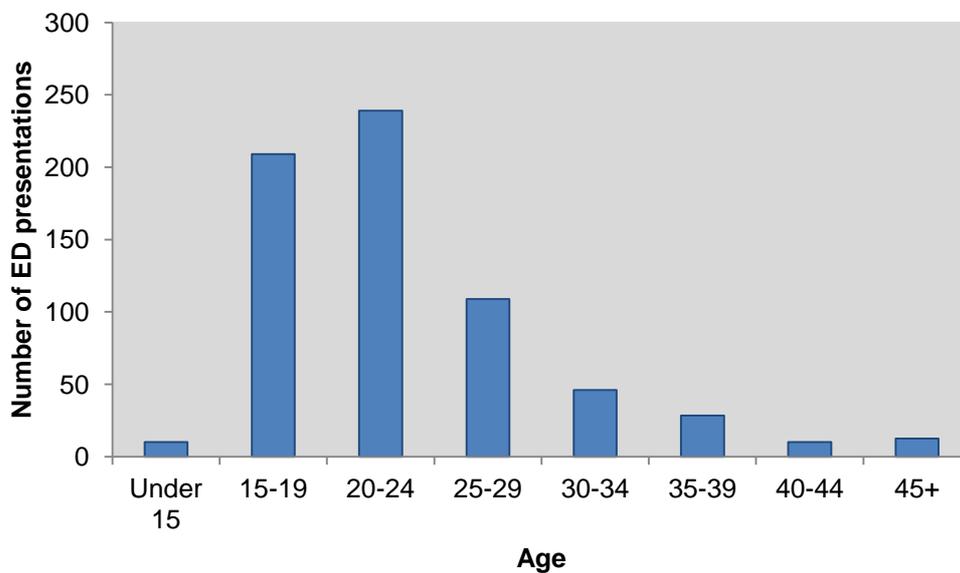


Figure 8. Number of emergency department presentations mentioning recent alcohol and energy drink consumption, by age

\*Where there are less than five presentations, the actual number has not been provided for confidentiality reasons. For graphical purposes, these have been given the value of 2.5.

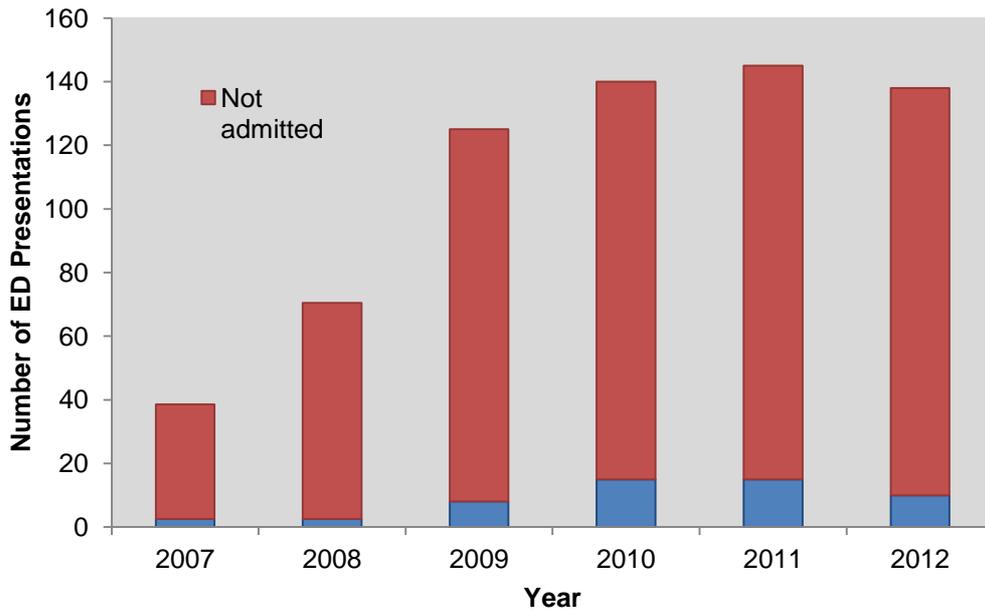
Sixteen percent ( $n=103$ ) of AED presentations to EDs involved the co-ingestion of illicit drugs. This figure was stable year-to-year. The most common illicit drugs reported among people presenting to the emergency department reporting AED use was ecstasy (52.4%;  $n=54$ ), cannabis (20.4%;  $n=21$ ), and methamphetamine powder (14.6%;  $n=15$ ) (see Table 11).

*Table 11. Number of people presenting to the emergency department reporting illicit drug use in addition to AED use*

<b>Illicit drug reported</b>	<b>Number of people reporting illicit drug use <math>n(\%)</math></b>
Ecstasy	54 (52.4%)
Cannabis	21 (20.4%)
Methamphetamine powder	15 (14.6%)
Cocaine	12 (11.7%)
Crystal methamphetamine	5 (4.9%)
Other	13 (12.6%)

\* The total does not add to 103 as some patients reported multiple illicit drug use

The majority of AED presentations to EDs over the six year period did not result in hospital admission (92%;  $n=604$ ). Of the 8% of presentations that did result in hospital admission, six of these resulted in critical care ward admissions. Of these six, three had co-consumed illicit drugs with AEDs. Figure 9 shows the number of the presentations that resulted in admission to hospital over the six year period.



*Figure 9. Number of emergency department presentations mentioning recent alcohol and energy drink consumption, by year and admission status*

\*Where there are less than five presentations, the actual number has not been provided for confidentiality reasons. For graphical purposes, these have been given the value of 2.5.

\*2012 data is from January 1<sup>st</sup> to November 30<sup>th</sup>

The most common symptoms experienced by AED users presenting to the emergency department (see Figure 10) included nausea and vomiting (experienced by 209 [31.8%] of all AED consumers), palpitations, chest pain/tightness, tachycardia and anxiety (all experienced by between 88 and 94 [13-14%] of patients).

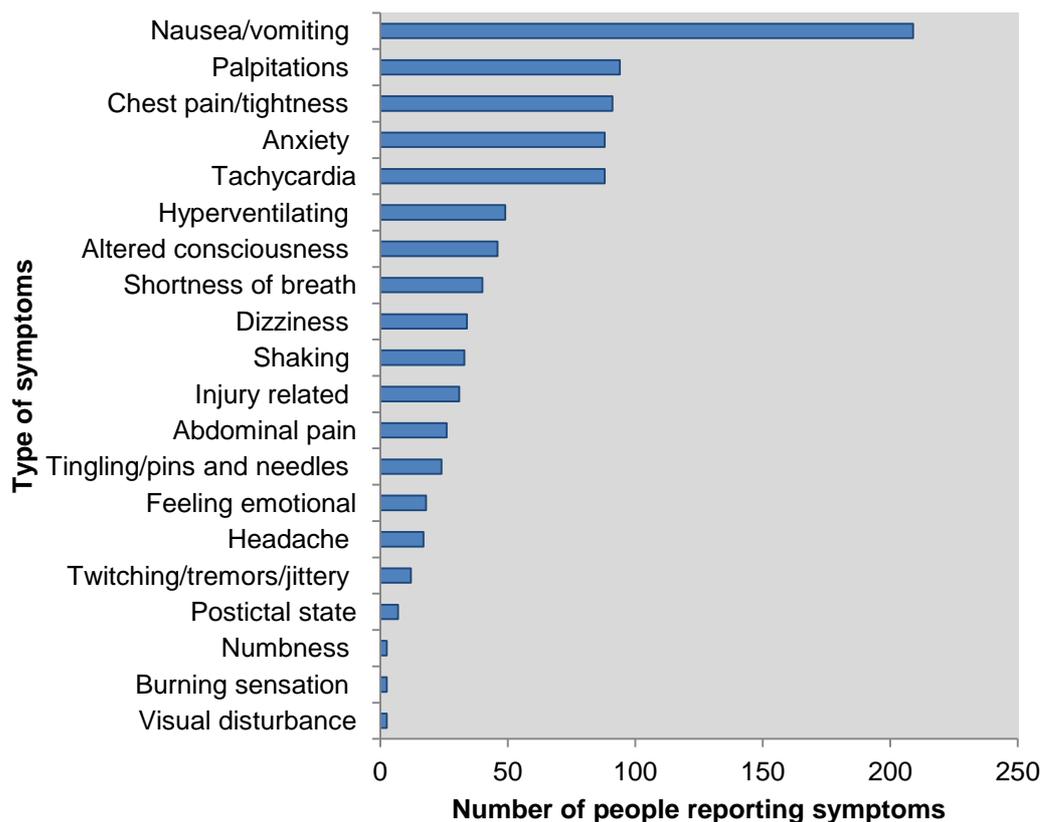


Figure 10. Number of people presenting symptoms relating to alcohol and energy drink consumption

\* The total does not add to 657 as patients presented with multiple symptoms.

\*Where there are less than five symptoms, the actual number has not been provided for confidentiality reasons. For graphical purposes, these have been given the value of 2.5.

### 3.4 Discussion

Thirty-nine poison centre calls related to AED use were recorded between 2004 and 2012, which represents 0.006% of all unique exposure-related calls to the NSWPIC. Poison centre calls peaked in 2008 and calls relating to recreational consumption of AEDs have remained relatively steady since then, with five or six per year.

There were 657 presentations related to AED use between 2007 and 2012 across 59 EDs in New South Wales, representing 0.00006% of all emergency department presentations during the same period. These numbers increased sharply from 2007 to 2009 but have remained relatively stable since that time, with around 120-140 presentations per year. It is difficult to compare this with US DAWN data, which reported 2,612 AED presentations in 2011 (as opposed to 145 in New South Wales in 2011); because the US has a much larger population and the DAWN report incorporates data from emergency departments across the US and it is not clear from DAWN data what proportion of emergency department presentations is represented by AED use. While AED presentations to NSW EDs have been relatively stable over the past few years, US presentations are increasing, and

as such further monitoring is required to ascertain whether these stable trends are maintained in NSW.

Broadly, the NSWPIC and emergency department data were consistent, giving us a good understanding of the stability of trends (with calls and presentations peaking in 2007-2009 and remaining stable since that time), the type of people experiencing serious harms from AEDs in terms of demographics and the types of harms experienced. For example, the number of calls relating to AED use was split evenly by gender in both the poison centre calls and emergency department presentations, suggesting that both males and females experience negative effects from consumption. In addition, most of the poison centre calls and emergency department presentations involved adolescents and young adults. One fifth of poison centre calls and one third of emergency department presentations involved adolescents, and suggests that people under the age of 19 are experimenting with AEDs and experiencing harms from use.

Where there was some difference between the two sources of data was in relation to polysubstance use. Over two thirds of poison centre calls involved the co-ingestion of AEDs with other substances. On the other hand, only one sixth of AED presentations to EDs involved the co-ingestion of illicit drugs (although this is likely to be underestimation based on self-report). One potential explanation for this discrepancy is that people who had used illicit drugs were reluctant to attend an emergency department and disclose illicit drug use, but were more likely to attempt to seek help over the phone. Stimulant drugs were the most commonly reported co-ingested illicit drugs with AEDs in poison centre calls and emergency department presentations. Most poison centre calls relating to AED use occurred between 6pm and 9am and most reported that the AED consumer had hand-mixed AEDs, with very few reporting the consumption of pre-mixed AEDs.

The primary symptoms reported in the context of poison centre calls included agitation, tremors, abnormally fast heartbeat, irregular heartbeat, and nausea and vomiting. This was consistent with side effects experienced by AED users presenting to the emergency department, which included nausea and vomiting, palpitations, chest pain/tightness, tachycardia and anxiety. These symptoms are broadly consistent with literature derived from self-reported surveys that report vomiting, nausea, heart palpitations, racing heart, tachycardia and anxiety (58, 122, 129, 132, 134, 135, 177); however, other common symptoms reported in the literature, such as serious hangover and insomnia/difficulty sleeping were not identified in NSWPIC calls and emergency department data, most likely because these are not usually serious enough to warrant presentation to acute services.

The majority of poison centre calls resulted in emergency department presentations (31 of 39), but the majority of the emergency department presentations did not result in longer-term hospital admission, indicating that AED presentations resolve fairly quickly. However, it is important to note that of the approximate<sup>10</sup> 50 presentations that did result in hospital admission, six of these resulted in critical care ward admissions.

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<sup>10</sup> This is an approximation as in years where less than five cases are reported an exact number is not given for confidentiality purposes.

### **3.4.1 Limitations**

Unfortunately there is very little data available from emergency services on AED use in New South Wales. In addition, the emergency department data that we were able to access was limited in the extent to which it could be analysed due to data custodian restrictions<sup>11</sup>. The data available through NSWPIC and NSW emergency departments are likely to represent a underestimation of AED-related harms that require emergency department or poison centre assistance, because of data coding problems (i.e., health professionals may not ask about energy drink use or may not record energy drink use appropriately) and because patients may not disclose energy drink use (due to intoxication, because they cannot remember or because it does not occur to them) (132). In addition, it was not feasible to search for all possible cases of AED consumption in the emergency department records, and knowledge of energy drinks is likely to vary among health professionals. Nevertheless, it is likely that NSW emergency department data presents a more accurate trend profile of harms related to AED use than NSWPIC calls because harms experienced from AED use are more likely to involve presentation to emergency departments than phone calls to PICs given that the majority of NSWPIC calls were referred to hospital, and also because many people may not have knowledge of PIC services. Whilst it is not feasible to change diagnostic coding structures (as these are standardised internationally), increasing awareness among health professionals and patients of the harms associated with AED consumption is likely to improve reporting and recording of AED consumption as a contributing factor to presentations over time. This will improve scope for monitoring AED-related harms.

A limitation of the emergency department and NSWPIC data was the limited data available regarding the quantity of alcohol and EDs consumed. Quantities were not able to be extracted from emergency department data and only reported for a minority of NSWPIC calls. Where reported in NSWPIC calls, the intake estimates were generally expressed as a range (e.g., 2 to 5 EDs), with the volume of the beverage rarely specified (i.e., 60mL, 250mL, or 500mL beverage). As such, average alcohol and ED intake for exposures reported to NSWPIC were not calculated. This absence of intake data could be partly attributed to the nature of AED consumption, as simultaneous consumption of alcohol and EDs can be achieved by purchasing pre-mixed beverages and by manually mixing the two constituents together, thus making retrospective recall of intake challenging, particularly when consumers are experiencing negative side-effects as a consequence of their intake.

### **3.4.2 Recommendations for future data collection**

It has been noted that there are significant limitations that inhibit our ability to examine trends in AED use and harms at a population level. Limited information is available through surveys, and also through routinely collected data across health and administrative systems. In order to address these gaps, a number of approaches could be employed to provide enhanced information regarding AED

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<sup>11</sup> Aggregated tables rather than raw data were provided to the project team meaning that additional analyses could not be run.

use and harms in NSW. However, it is necessary to consider any recommendations in the context of cost, anticipated benefit, and impact on services.

## **Surveys**

Population surveys provide an opportunity to obtain valuable information to enable quantification of patterns of AED use in the general population, and in specific sub-populations. However, the commissioning of new surveys is highly costly, and there is limited utility in the administration of a new, representative general population survey if there is no scope for repeated population sampling.

Accordingly, the greatest utility in collection of survey data is through the use and expansion of existing surveys to include questions regarding AED use. This is particularly useful where questions relating to alcohol use patterns are already included, and is comparatively cost effective as opposed to the commissioning of new general population surveys. Two recommended options that include sufficient state-by-state data are the National Drug Strategy Household Survey (NDSHS) and the Australian School Students Alcohol and Drug Survey (ASSAD).

In addition, the inclusion of questions relating to AED in surveys of populations more likely to use AED, or at greater risk of harm associated with AED, represents an opportunity to develop enhanced knowledge regarding use patterns and potential opportunities to prevent and reduce harm. The findings presented here indicate that surveys sampling populations of young people and illicit drug users would also provide valuable information on AED use.

## **Ambulance Attendances**

Ambulance data has the potential to provide valuable information regarding acute harms associated with AEDs. Currently, information regarding AED involvement in ambulance attendances is not readily available. However, additional review and coding of ambulance data for AED use has commenced in Victoria, and should be considered in New South Wales as part of ongoing monitoring and surveillance of trends in AED harms. Such a system would involve additional case classification and coding as is currently undertaken in Victoria. Importantly, such additional work does not require any changes or additional activities for paramedics or the Ambulance Service of New South Wales, as the Victorian model is undertaken by alcohol and drug researchers, who have specialist expertise in this area. The Victorian system could be applied to data collected in New South Wales, and would involve the costs associated with classification, coding and analysis only, as the underlying system has already been developed and refined.

## **Emergency Department Presentations**

Emergency department data provides an important basis for the monitoring of AED harms. Changing coding systems and clinical practice in emergency department settings to fundamentally shift the nature of recording of AED would involve substantial cost – both in terms of financial investment, and also training and staffing resources. We feel that this is not a feasible approach, and that regular review of emergency department data – as was conducted for this study – is the most efficient and

appropriate approach to extract data regarding AED-related presentations to EDs. Based on the numbers of cases identified in this study, annual review of emergency department data (incorporating the search terms used in this study) to monitor AED-related presentations would be appropriate, and would provide a valuable tool for monitoring AED-related harms.

### **Hospital Admissions**

Preliminary analysis of hospital data was conducted as part of this study, and yielded poor results in terms of any meaningful information pertaining to AED-related admissions. Furthermore, the results presented for emergency department presentations indicate that very few AED-related presentations to emergency departments result in hospital admission. Accordingly, we feel that little would be gained by implementing any changes to attempt to improve available AED harms data in hospital admissions routine data collection. However, following the upcoming implementation of new diagnostic coding (with the introduction of ICD-11), it would be worthwhile reviewing data quality regarding AED-related cases.

### **Deaths Data**

In this study, preliminary consideration of deaths data as a possible indicator of harms associated with AED use confirmed that only coronial data had the potential to inform measures of AED involvement in deaths. This is because toxicological indicators of AED consumption would be required to determine AED involvement in deaths. The comparatively low numbers of NSWPIC cases and emergency department presentations over the period examined, indicates that the substantial work that would be involved in analysis and review of coronial data would be unlikely to yield sufficient cases to be useful as evidence to support prevention and intervention initiatives. Given the small number of AED related cases in morbidity data (NSWPIC and EDs), it is reasonable to conclude that AED would rarely be a contributor to coronial cases. For the purposes of future monitoring and surveillance of AED harms, we recommend that no changes be made to coding or review of coronial data, and that this recommendation be reviewed if marked increases in AED related morbidity are identified, or in the event that AED become a feature of multiple coronial cases.

### **Poisons Information Centre**

Poisons information centre (NSWPIC) data has provided a valuable source of information for this study, and the current system provides a useful basis for ongoing monitoring of cases. It is recommended that regular review of cases be conducted as part of ongoing monitoring activity to support surveillance of AED-related harms in the population of NSW. Based on the numbers of cases identified in this study, review of NSW PIC data (incorporating the search terms used in this study) to monitor AED-related presentations would be appropriate on a five-yearly basis, and would provide a valuable tool for monitoring AED-related harms. However, if continued monitoring of emergency department data indicates an upward trend in cases involving AED toxicity, it is recommended that the frequency of exploration of NSW PIC cases be reviewed to ensure that any emerging patterns of harm are adequately identified and addressed. Greater emphasis could be placed on obtaining

specific estimates of alcohol and ED intake where possible to provide further information regarding the threshold at which adverse side-effects become apparent.

### **Summary of Recommendations**

Through review of existing data sources, and gaps in available information regarding AED use and related harms, the following recommendations have been developed:

- Questions relating to AED be added to existing general population surveys;
- Questions relating to AED be added to existing surveys accessing high risk subpopulations such as youth and illicit drug users;
- Enhance additional coding of ambulance attendance data to enable identification of AEDs;
- Conduct regular review of emergency department presentations data (utilising search terms for case notes) to monitor trends in presentations; and
- Conduct regular monitoring of calls to the NSW Poisons Information Centre to identify trends in AED harms.

### **Conclusion**

At present, there is very little secondary data that can be sourced in NSW to paint a comprehensive picture of the nature of harms from AED use. What data were available reveals that there have been very low numbers of AED-related calls to NSWPIC and NSW emergency departments over the past nine years, suggesting that AED use is not placing a significant burden on acute emergency services. However, these numbers are likely to represent an underestimation of the harms associated with AED use due to poor recording of alcohol and energy drinks in routine data collection systems. It does appear that AED health-related harms have increased over time. It will be important to regularly monitor these trends to ensure they don't increase substantially, and it is important to ensure that data is collected in the most accurate way to ensure that harms from AED use are not going unrecorded. In particular, routine collection of AED-related presentations through ambulance services is likely to be important as paramedics in Melbourne have reported that they often treat AED users at festivals and around licensed venues without transporting them to emergency departments (132). However, it is reasonable to conclude that AED consumption would rarely be a contributor to coronial cases, and we do not recommend that coronial data be reviewed unless increases in AED related morbidity are identified.

## 4. SURVEY FINDINGS

### 4.1 Introduction

While US research shows that between 15% and 50% of university students consume AEDs and AED consumers are more likely to be Caucasian, male and young (18-30 years), little is known about the popularity of AED use in Australia and socio-demographic characteristics of Australian AED users. International survey research shows that AED users are more likely to exhibit riskier drinking practices, including the tendency to consume alcohol more frequently and consume higher quantities of alcohol per session, relative to non-AED users, and display a higher propensity for risk-taking and engagement in more risk-taking behaviours. However, it is unclear whether this is because people high in risk-taking propensity are attracted to AED consumption and/or whether AED consumption causes increases in risk-taking behaviour. Studies that have attempted to understand the direction of this relationship using within-subjects designs have revealed mixed findings.

Survey and qualitative research conducted internationally and in Australia indicate that AED users consume these drinks for four main benefits: a) the stimulant properties of caffeine facilitate wakefulness and energy; b) the sweet, palatable taste of AEDs provide a more appealing beverage and mask the flavour of alcohol; c) drowsy drunkenness is reduced and a more desirable drunkenness is facilitated; and d) alcohol consumption and intoxication is facilitated. The self-reported side-effects associated with AED consumption (elicited from surveys) include: a) dehydration and worse hangover (self-reported as worse relative to alcohol-only sessions); b) sleeping difficulties; and c) physiological impairment such as increased heart rate, palpitations, gastrointestinal upset, vomiting and nausea.

Using both a web-survey and a night-time street intercept survey, this component of the research aimed to understand how widespread the practice of mixing alcohol and energy drinks is amongst the NSW population, the demographics of AED users in NSW and the patterns, motivations and harms of AED use among NSW residents. Both a web-survey and street intercept survey were deemed the most suitable and cost-effective way of reaching the population of interest (i.e., young people and those using AEDs at night). General population-based studies assessing alcohol and other drug use are typically unrepresentative of young people, particularly those engaging in heavy alcohol and other drug consumption, and suffer from poor response rates. Traditional telephone surveys fail to access people who do not have mobile telephones or live in alternative forms of accommodation. However, our recent work has shown that street intercept surveys have been very successful in reaching young people who consume AEDs and who frequent night-life precincts. They also achieve high response rates. A web-based survey was also conducted to gather additional information from a broader sample of young people across NSW. Recruitment via social media was considered likely to afford greater access to young people via their medium of choice – the internet. The online survey had the added benefit of accessing young people from rural and regional areas. The results of the two survey components are presented separately given their unique methodology and different populations.

## 4.2 Aims

The survey component of the study sought to investigate:

- Patterns of AED consumption amongst the NSW population;
- Identification of the key demographic groups engaging in AED consumption;
- Motivations for and against ED/AED consumption; and
- Experience of side effects or negative consequences as a result of AED consumption.

## 4.3 Web Survey

### 4.3.1 Methods

#### 4.3.1.1 Measures

The web-survey contained the following sections:

- Introduction and consent;
- Demographic data (i.e., age, gender, etc.);
- AUDIT-C (a standardised psychological scale measuring alcohol consumption - 178);
- Alcohol use, ED use and AED use, including patterns and contexts of use;
- Why/why not use EDs and AEDs (i.e., motivations/experience of harms);
- Use of premixed AEDs; and
- Aggression/violence and risk-taking.

#### 4.3.1.2 Recruitment Strategies

A multi-faceted online advertising campaign was utilised to recruit participants. Paid advertising included Facebook and popular social events planning website TimeOut Sydney. Facebook enabled a focused campaign directed at the required demographic (people aged 16-35), and was modified over the course of data collection in order to maintain a balanced sample and increase recruitment. Specific campaigns focused on people who had 'liked' live music festivals and venues, brands of energy drinks and premixed AEDs, popular alcohol brands, sporting teams and dance music culture. TimeOut is one of the most popular online social event planners and has iterations for Sydney, Melbourne, New York and other cities worldwide. TimeOut caters specifically to the target demographic, which are people who attend events such as live music, bars, clubs, arts festivals and restaurants.

In addition to paid advertising, press releases were issued from consortium partners and email snowballing was utilised amongst professional networks. Links to the survey were also posted on internet forums, such as Bluelight's Drug Studies page (<http://www.bluelight.ru/vb/forums/180-Drug-Studies>). In addition, an email with a link to the web-survey was distributed to University of Newcastle students, and postgraduate students at University of Western Sydney. Additionally, members of the National Drug and Alcohol Research Centre (NDARC) were contacted with survey details. It is important to consider that the sample is not representative of the NSW population because young

AED users were deliberately and non-randomly targeted through recruitment. All participants entered the draw to win one of 10 Apple iPads.

#### **4.3.1.3 Sample Size**

The required sample size was determined largely by three factors: (i) the estimated prevalence of the variable of interest – AED use in this instance, (ii) the desired level of confidence and (iii) the acceptable margin of error. There is poor prevalence data for AED use; however, as identified in the literature review, the available international data suggests that around 25-30% of particular samples have used AEDs in the past month. Based on this, it was expected that around 2 million people in NSW had recently used energy drinks. Using sample size calculators from SurveyMonkey (<http://www.surveymonkey.com/mp/sample-size/>) and SurveySystem (<http://www.surveysystem.com/sscalc.htm>), the recommended minimum sample size was 384, which was achieved and exceeded.

#### **4.3.1.4 Survey Procedure/Administration**

The web-survey was completed online and comprised of multiple choice, scale based and text entry fields. Participants read a plain language statement on the first page of the survey, prior to commencement, which contained details of ethics approval through Deakin University and investigator and ethics contact details. Informed consent was implied by survey commencement. The only exclusion criteria for the survey was being under the age of 16 or living outside of NSW. Participants were informed they were able to withdraw from the survey at any time.

Survey completion typically took between 15-35 minutes depending upon the participants' substance use history; the survey was reactive and removed redundant items on a case-by-case basis. Data was collected for a period of 12 weeks between December 2012 and February 2013 and all survey data was non-identifiable.

For the purpose of the survey energy drinks were defined to participants as "any caffeinated drink which is advertised primarily as providing benefits to physical and mental performance, endurance, concentration and/or stamina." In an effort to standardise consumption data for energy drink use amongst participants to approximately 80mg per serve, "standard" size energy drinks were operationalised as follows:

- 1 x 60ml shot energy drink = 1 standard energy drink
- 1 x 250ml standard energy drink = 1 standard energy drink
- 1 x 500ml supersize energy drink = 2 standard energy drinks

In order to ensure that each participant was unique, participant Internet Protocol (IP) addresses were collected and stored independently of survey responses. This ensured that once completed, the survey could not be accessed a second time from the same computer. The addresses were discarded at the completion of data collection.

#### **4.3.1.5 Data Analysis**

Data was collected and stored using online survey tool Survey Monkey. All analyses were conducted using IBM SPSS Statistic v.21 for Mac (179). Frequency and descriptive statistics were calculated for all categorical variables. Mean, standard deviation (SD) and range figures were calculated for numerical and scales variables. Paired sample t-tests, independent sample t-tests, and chi-square tests were used to test the statistical significance of differences between and within sample groups. Effect size of differences is represented using Cohen's *d* statistic. Effect size is a measure of the strength of the relationship between two variables. In this chapter they accompany t-tests, to help explain the significance of differences between groups of participants, for example AED users versus non-AED users. While t-tests may produce a significant difference (p value), they can sometime be inflated due to large sample sizes, such as those presented here, and therefore the significant value may be limited in its meaning or effect. To overcome this, we have used Cohen's *d* statistic, a score which ranges from 0 to 1, and provides an indication of the real world impact of the finding. A description of the effect size (e.g., moderate, strong, weak, etc.) is provided for ease of interpretation. More information on Cohens *d* can be found in this reference (180).

Depending upon their level of survey completion (i.e., the amount of missing data), individual participants may have been removed from the dataset (further details below).

#### **4.3.2 Results**

##### **4.3.2.1 Description of the Sample**

Data collection concluded on Monday 18<sup>th</sup> of February 2013, at which point  $n=2,953$  unique participants had commenced the survey. Table 12 provides a summary of cases removed from analysis as a result of incomplete responses or numerical outliers. Cases were removed if they were missing data for items deemed critical to the research question or the progress logic of the survey (e.g., energy drink or alcohol use). After data cleaning the inclusion rate was 65.3%, yielding a final sample size of  $n=1,931$ . Further missing data is declared for each analysis presented.

Table 12. Summary of cases removed from analysis

Reason for Removal	(n)
<i>Summary</i>	
Age below ethics range	5
Age data missing	21
Non NSW residents	228
No response to any alcohol use items	50
No response to any ED use items	446
No response to any combined AED use items	109
No response to any harm/aggression or side effect items	148
Numerical outliers on substance use items	14
Aggressive incident report outlier	1
TOTAL REMOVED	1022

Participants' ages ranged between 16 and 70 years old, with 76.7% of the sample aged 30 years or below. The mean age of respondents was 26.5 ( $SD=9.3$ ) and the most commonly reported age was 20 (see Figure 11). By comparison, 2011 census data indicates that 19.7% of the NSW population fall between the ages of 14 and 30, with a median age of 38 (181). Almost two thirds (63.7%) of the sample were female. Over a third (36.5%) of the sample identified as not being in a current relationship, compared to a NSW population figure of 41.7% (181). Almost two thirds (64.1%) of the sample earned a gross income of less than \$35,001 per annum (see Table 13).

Table 13. Descriptive statistics for demographic variables

Variable	(n)	%
<i>Gender</i>		
Male	692	35.8%
Female	1231	63.7%
Missing	8	0.4%
<i>Age Bracket</i>		
16-17	46	2.4%
18-20	483	25.0%
21-25	682	35.3%
26-30	270	14.0%
31-40	258	13.4%
40 and over	192	9.9%
<i>Relationship Status</i>		
Not in a relationship	704	36.5%
Serious/Stable	353	18.3%
Married/legal partnership	327	16.9%
Casually dating	251	13.0%
De-facto	248	12.8%
Divorced	19	1.0%
Separated	16	0.8%
Widowed	5	0.3%
Missing	8	0.4%
<i>Gross Income</i>		
not answered	8	0.5%
\$20,000 or lower	955	49.5%
\$20,001 to \$35,000	273	14.1%
\$35,001 to \$50,000	132	6.8%
\$50,001 to \$65,000	130	6.7%
\$65,001 to \$80,000	125	6.5%
\$80,001, to \$100,000	92	4.8%
More than \$100,000	102	5.3%
Prefer not to answer	113	5.9%
<i>Highest Education Completed</i>		
Missing	11	0.6%
Advanced Diploma/Diploma or equiv.	130	6.7%
Bachelor Level	421	21.8%
Certificate/Apprenticeship	120	6.2%
Completed HSC/HEC (Year 12 or equiv.)	840	43.5%
Honours/Graduate Diploma Level	112	5.8%
PostGrad Degree Level	240	12.4%
Year 10 or equivalent	54	2.8%
Year 8 or below	1	0.1%
Year 9 or equivalent	1	0.1%

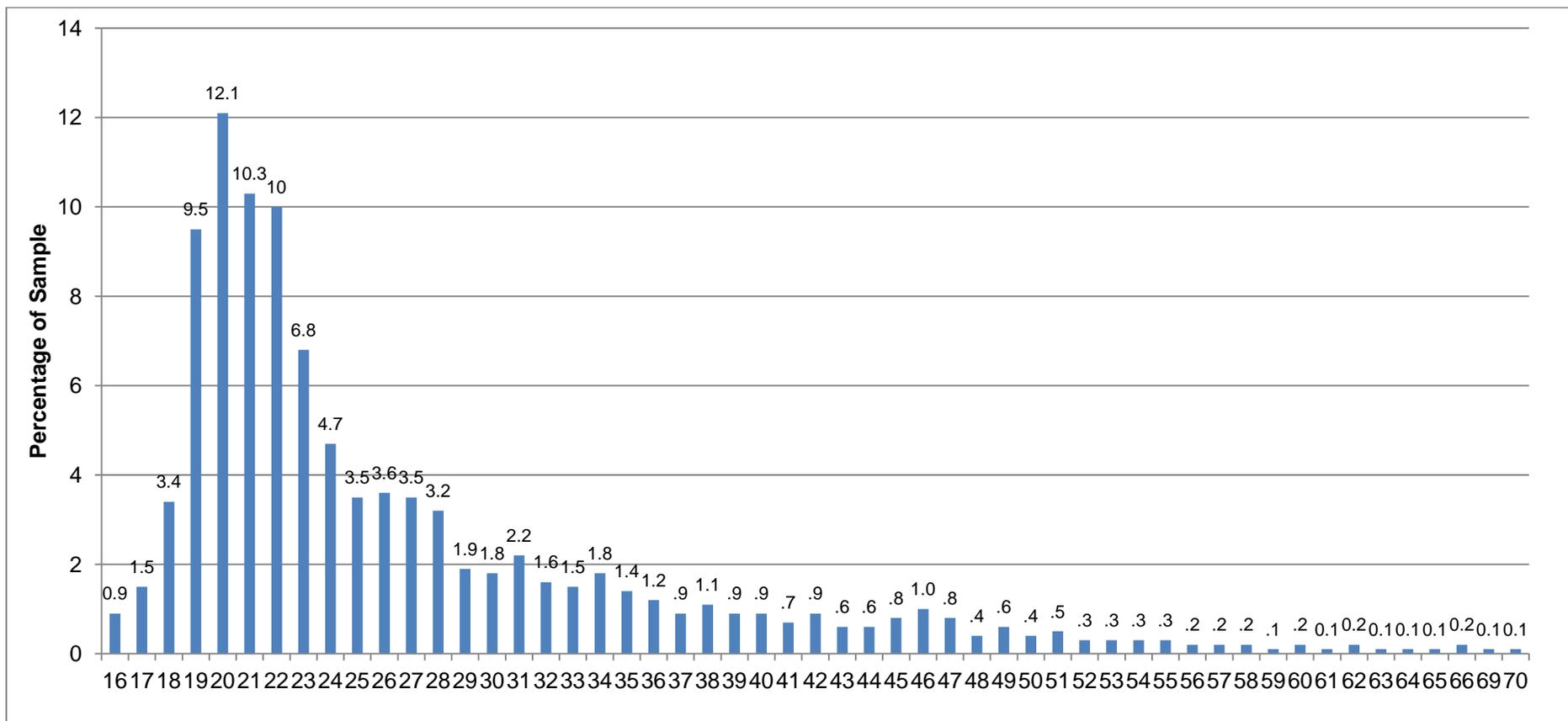


Figure 11. Sample distribution of age (% per year)

In total, survey participants were recruited from 295 unique NSW postcodes. The top 50 most frequently reported postcodes are indicated graphically in Figure 12, and account for approximately two thirds (69%) of the sample in total. Survey respondents were most frequently recruited from coastal districts around the Central Coast, Wyong, Newcastle, Sydney Metropolitan area and Lake Macquarie. Respondents in Newcastle and surrounding districts represent a substantial proportion of the sample, due to a successful email recruitment campaign issued through University of Newcastle.



Figure 12. Location of top 50 most frequently reported postcodes

Postcode data was also used in order to assign ARIA codes (Accessibility/Remoteness Index of Australia - 8). ARIA codes are based upon an index score of remoteness, calculated according to road distances to the nearest available service centres. The classes have been characterised broadly as follows:

1. Highly Accessible—relatively unrestricted accessibility to a wide range of goods and services and opportunities for social interaction;
2. Accessible—some restrictions to accessibility of some goods and services and opportunities for social interaction;
3. Moderately Accessible—significantly restricted accessibility of goods and services and opportunities for social interaction;
4. Remote—very restricted accessibility of goods, services and opportunities for social interaction;
5. Very Remote—very little accessibility of goods, services and opportunities for social interaction (8).

At a population level, the ARIA classification system defines 81% of Australians as living in the most accessible class (Highly Accessible areas). ARIA classifications for the current sample are shown in

Figure 13. In total, 92.9% of respondents lived in a highly accessible area, indicating that the web survey sample had a slightly higher proportion of city/metropolitan residents than the general population.

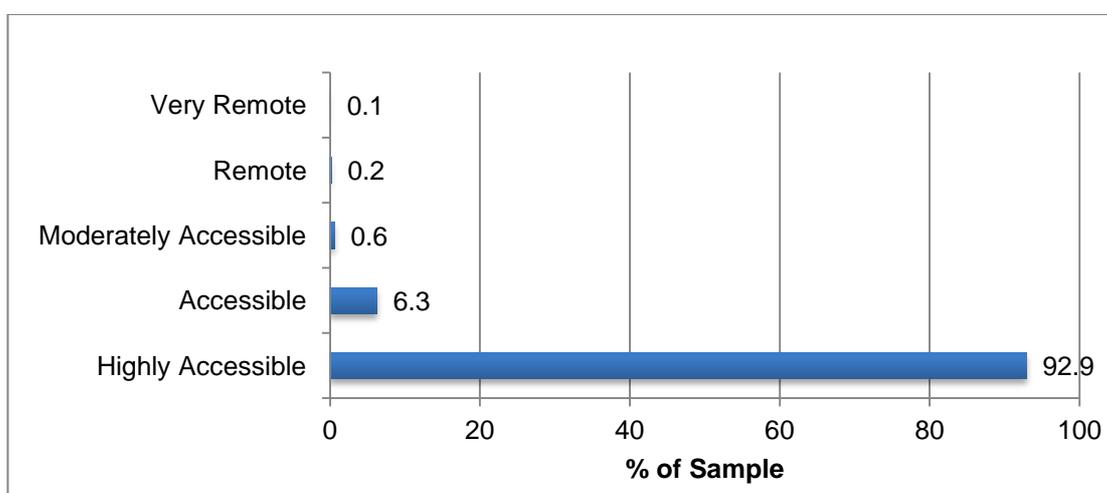


Figure 13. Sample ARIA classification (%)

\*129 cases did not report postcode data.

In total, 36% of respondents reported that they were currently “studying only”, while 29.3% reported combining work and study (Table 14). In contrast, approximately 46% of 20-24 year-olds in New South Wales attend schools or other educational institutions (181).

Table 14. Current employment status of participants

Employment status	(n)	%
Studying only	704	36.5%
Study/work	566	29.3%
Casual	438	22.7%
Part-time (30hrs or less)	324	16.8%
Full-time	497	25.7%
Unemployed	70	3.6%
Self-Employed	41	2.1%
Carer	18	0.9%
Pensioner/retired	8	0.4%

\*multiple choice item: sum is greater than 100% due to multiple selections.

Most respondents (78.9%) were enrolled in some form of education, with 59.0% studying a Bachelor Degree or equivalent tertiary degree. Eleven percent of participants were not currently studying (Table 15). The high proportion of students is a consequence of the large number of University of Newcastle students who completed the survey.

Table 15. Current education status of participants

Enrolled	(n)	%
None	177	21.1%
Yr. 10 or equivalent	7	0.4%
Yr. 12 or equivalent	28	1.5%
Certificate/ Apprenticeship	28	1.5%
Advanced Diploma/Diploma or equivalent	18	0.9%
Bachelor Level	1140	59.0%
Honours/Graduate Diploma Level	74	3.8%
Postgraduate Degree Level	227	11.8%

#### 4.3.2.2 Substance Use

The majority of participants were not current tobacco users, with 77.6% reporting that they had not consumed tobacco in the preceding 12 months. Only 6.5% reported smoking tobacco products daily. Majority of participants (78.0%) had not used illicit substances in the past 12 months. Cannabis was the most widely reported substance (16.9%), followed by the stimulants ecstasy (8.3%), cocaine (5%), and methamphetamine (3.5%).

#### 4.3.2.3 Alcohol Use

In total, 91.4% of respondents ( $n=1,765$ ) reported having consumed an alcoholic drink in the past 12 months. Overall frequency of alcohol consumption for the whole sample is shown in Figure 14. Respondents most commonly reported drinking “2 to 4 times per month” (34.1% of the sample).

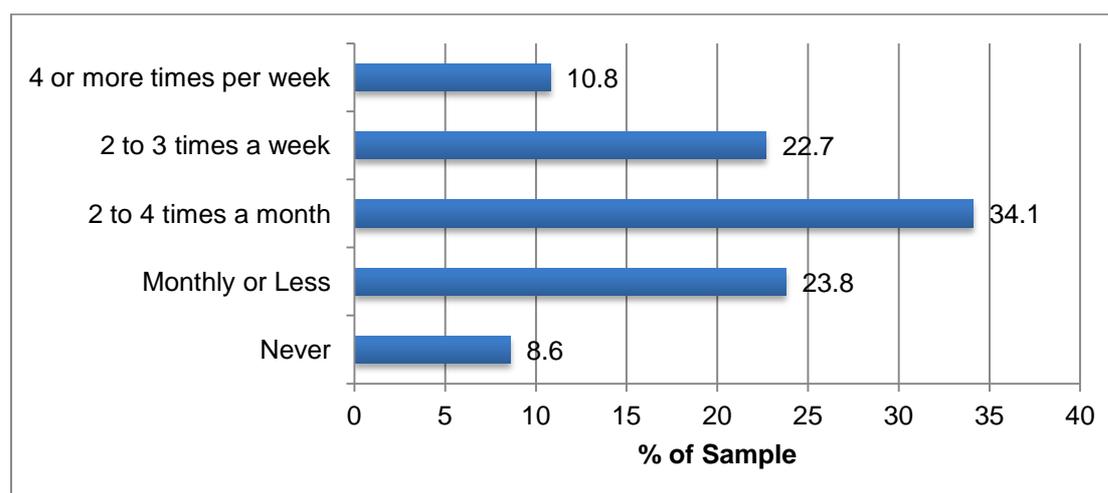


Figure 14. Audit-C frequency of alcohol use in past 12 months

Self-reported number of drinks consumed during a typical drinking session ranged between 0 and 26, with almost two thirds (65.6%) reporting less than 6 standard drinks per typical session (Table 16). Male participants and those aged 18-20 inclusive consumed the highest amount of alcohol during typical sessions when compared to the sample mean of 4.9 standard drinks (SD=3.7).

Table 16. Descriptive statistics for all alcohol users

Variable	Mean (SD)	Male	Female
Number of drinks on typical session in past 12 months (range: 0-26)	4.9 (3.7)	6.0	4.3
Age 16-17	4.7 (4.4)	4.9	4.3
Age 18-20	5.9 (3.9)	7.3	5.2
Age 21-25	5.3 (3.8)	6.6	4.5
Age 26-30	4.8 (3.6)	6.1	4.1
Age 31-40	3.6 (2.7)	3.8	3.5
Age 40 and over	2.7 (1.9)	3.1	2.6
Max number of drinks in session in past 12 months (range: 0-60)	10.9 (7.5)	14.5	8.9
Age 16-17	8.8 (6.1)	8.8	8.8
Age 18-20	12.1 (8.4)	16.5	9.6
Age 21-25	11.9 (7.4)	16.0	9.7
Age 26-30	11.7 (7.5)	15.7	9.5
Age 31-40	8.8 (6.2)	10.6	7.9
Age 40 and over	6.2 (4.2)	8.1	5.3
Age of first full alcoholic drink (years) (range: 3-30)	15.9 (2.1)	15.9	16.0

The maximum number of drinks consumed in a single session were substantially higher than those reported for a typical session ( $M=10.9$ ,  $SD=7.5$ ). Males demonstrated the highest rates of maximum alcohol consumption ( $M=14.5$ ). Most of the sample (77.8%) reported consuming more than 6 drinks on at least one occasion in the past 12 months, an indicator for high risk alcohol consumption included as part of the AUDIT-C screening tool (Figure 15). Further, one quarter of the sample (26.3%) reported consuming 15 or more drinks in one session within the past 12 months.

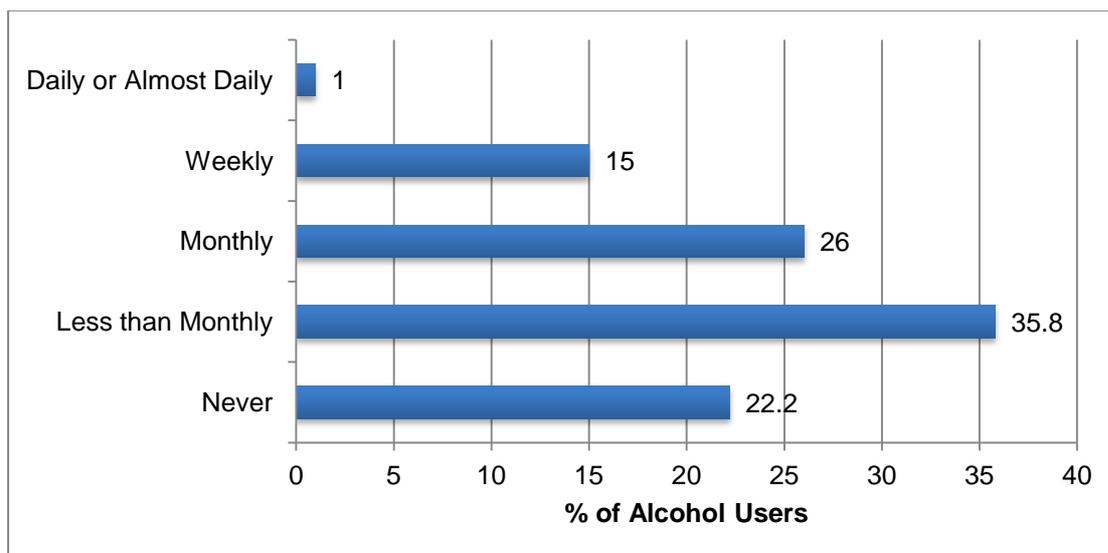


Figure 15. Frequency of high risk alcohol use - 6 or more drinks on one occasion

It is important to note that levels of alcohol consumption in this sample are significantly higher than levels of alcohol consumption among people of similar age in general population samples such as the National Drug Strategy Household Survey (1). This is most likely an outcome of our targeted sampling towards those who are likely to go out and consume alcohol in the night-time economy, but does provide useful new information about levels of alcohol consumption among young people in this context, and is likely to be important for understanding increases in alcohol-related hospital presentations (3).

#### 4.3.2.4 Energy Drink Use

In total, 58.8% of respondents ( $n=1136$ ) reported having consumed an energy drink in the past 12 months. Overall frequency of energy drink consumption for ED users is shown in Figure 16 below. The most commonly reported frequency for ED consumption was “monthly or less”, reported by 57.7% of ED consumers.

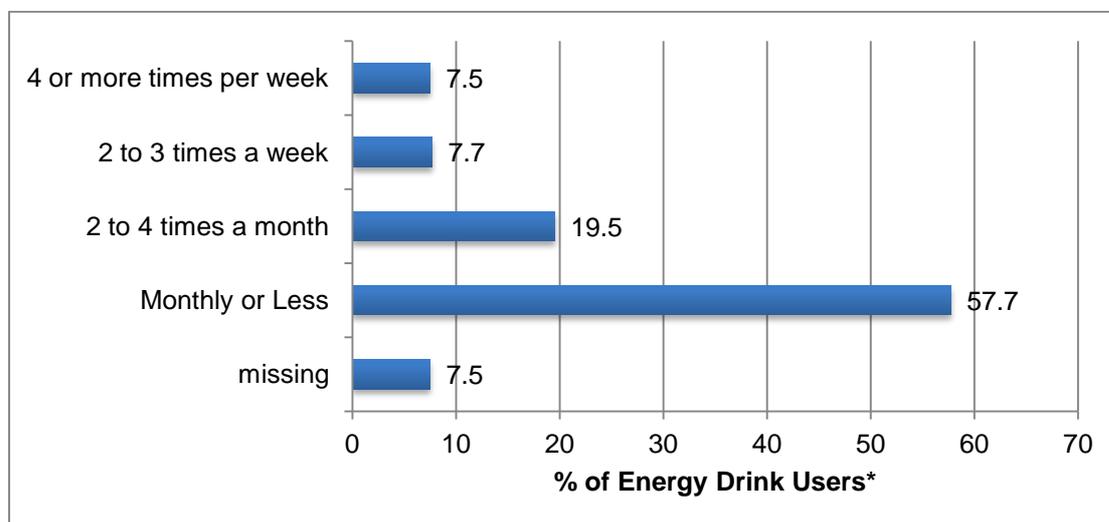


Figure 16. ED users - Frequency of ED use in past 12 months

\*86 cases were missing data for this item

Self-reported number of energy drinks consumed in a typical session/occasion ranged between 0 and 12, with the majority (92.5%) reporting two or less standard energy drinks per typical session, the recommended maximum daily consumption limit in Australia. Male participants and those aged 26 and over consumed the highest amount of unmixed energy drinks during typical consumption occasions when compared to the sample mean of 1.4 standard energy drinks ( $SD=1.0$ ), with the highest demographic bracket being male participants aged 40 and over consuming 2 drinks ( $M=2.0$ ) standard energy drinks on average in a typical session.

The maximum number of energy drinks consumed on a single occasion were higher than those reported for a typical session (Table 17). Males demonstrated the highest rates of maximum unmixed energy drink use ( $M=2.8$ ,  $SD=2.3$ , Table 17). The highest reported figures for “maximum” sessions was among 16-17 year old males, who reported a mean 3.4 standard energy drinks in maximum sessions.

Table 17. Descriptive statistics for all unmixed ED users

Variable	Mean (SD)	Male	Female
Number of EDs on typical session in past 12 months (range: 0-12)	1.4 (1.0)	1.6 (1.2)	1.3 (0.9)
Age 16-17	1.3 (0.7)	1.6	1.0
Age 18-20	1.4 (1.0)	1.6	1.3
Age 21-25	1.4 (0.9)	1.5	1.3
Age 26-30	1.4 (1.2)	1.7	1.2
Age 31-40	1.3 (1.4)	1.5	1.2
Age 40 and over	1.6 (1.4)	2.0	1.2
Max number of EDs in a session in past 12 months (range: 0-27)	2.3 (2.6)	2.8 (2.3)	2.0 (2.0)
Age 16-17	2.5 (1.5)	3.4	1.6
Age 18-20	2.4 (2.1)	3.2	1.8
Age 21-25	2.5 (2.4)	2.8	2.2
Age 26-30	2.2 (2.4)	2.8	1.9
Age 31-40	1.8 (1.3)	2.0	1.6
Age 40 and over	1.9 (1.3)	2.3	1.6

Thirty six percent of ED consumers reported having consumed over the recommended daily consumption in the last 12 months. However, this appeared to occur relatively infrequently amongst respondents, with the majority of ED users consuming 3 or more EDs in a single session doing so less than monthly (Figure 17).

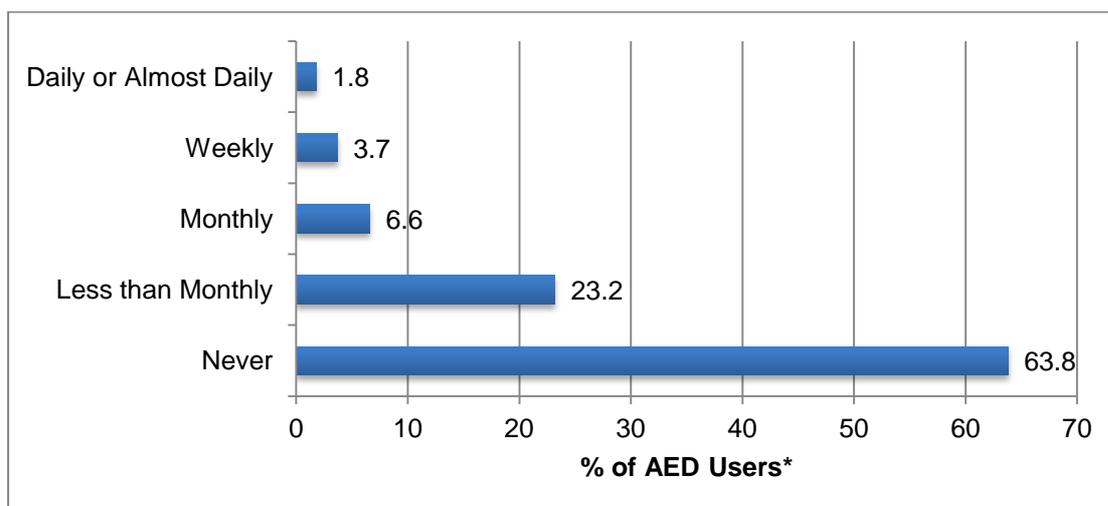


Figure 17. ED Users - Frequency of high risk ED use: 3 or more drinks on one occasion

\*11 cases were missing data for this item

#### 4.3.2.5 Alcohol and Energy Drink Use

In total, 37.9% of respondents ( $n=731$ ) reported having combined alcohol and energy drinks in the past 12 months. Overall frequency of AED consumption for AED users is shown in Figure 18. The most commonly reported frequency for AED consumption was “monthly or less”, reported by 80% of the AED users.

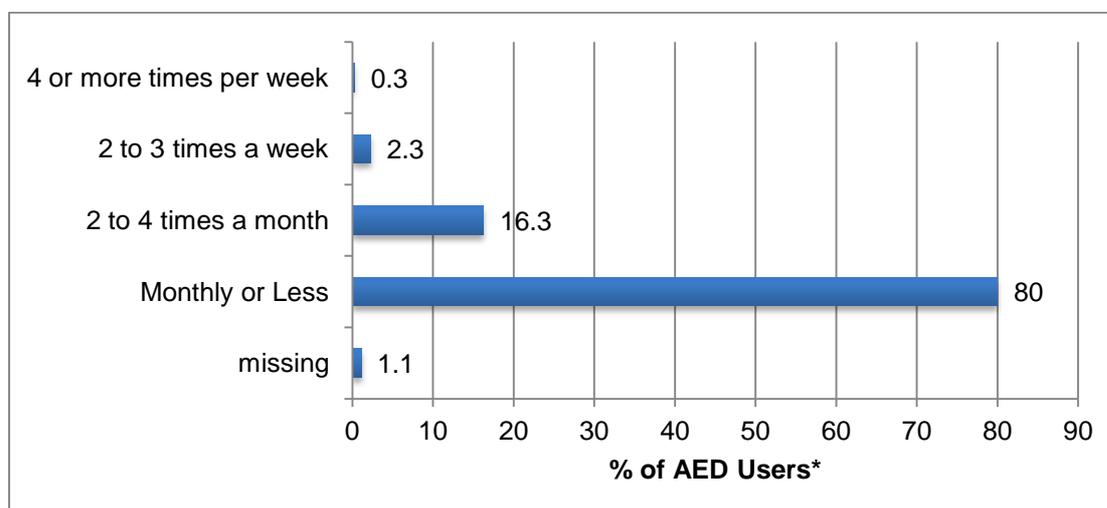


Figure 18. AED users - Frequency of AED use in past 12 months

\*8 cases were missing data for this item

AED users reported consuming an average of 5.9 alcoholic drinks and 3 energy drinks in typical AED sessions; and 8.2 alcoholic drinks and 3.8 energy drinks in maximum AED sessions. Participants reported that during AED sessions, approximately 31% of their drinks were AEDs (Table 18).

Almost half (41.5%) of AED users reported that they consumed more than 2 standard energy drinks in a typical AED session, exceeding recommended daily intake ( $M=3.0$ ,  $SD=2.6$ ). When asked to report maximum energy drink consumption during an AED session, 56.2% of AED users consumed more than the recommended daily limit of 2 energy drinks.

AED use was more prevalent amongst male participants than females (34.7% of females had used AEDs within the past 12 months, compared to 43.6% of males). Participant age did not have a predictable or consistent relationship with quantities of AED use (Table 18); however, younger people were more likely to use AEDs (Table 19).

Table 18. Descriptive statistics for all AED Users

Variable	Mean (SD)	Male	Female
Number of EDs on typical AED session in past 12 months (range: 0-20)	3.0 (2.6)	3.6 (3.1)	2.6 (2.0)
Age 16-17	2.4	2.4	2.5
Age 18-20	3.0	3.8	2.5
Age 21-25	3.0	3.5	2.7
Age 26-30	2.9	3.6	2.4
Age 31-40	2.9	3.0	2.8
Age 40 and over	3.2	-	1.7
Maximum number of EDs in AED session in past 12 months (range: 0-20)	3.8 (3.0)	4.3 (3.4)	3.4 (2.6)
Age 16-17	2.8	2.5	3.6
Age 18-20	3.8	4.6	3.3
Age 21-25	4.0	4.4	3.7
Age 26-30	3.4	4.1	2.9
Age 31-40	3.4	4.0	3.1
Age 40 and over	2.8	-	2.1
Number of Alcoholic Drinks on typical AED session in past 12 months (range: 0-25)	5.9 (4.1)	7.4 (4.9)	4.9 (3.2)
Age 16-17	4.1	4.3	4.0
Age 18-20	6.2	8.0	5.0
Age 21-25	5.7	7.1	4.8
Age 26-30	6.5	8.5	5.2
Age 31-40	5.7	7.2	4.7
Age 40 and over	4.3	-	4.1
Maximum number of Alcoholic Drinks in AED session in past 12 months (range: 0-50)	8.2 (6.7)	10.9 (8.0)	6.3 (4.7)
Age 16-17	6.2	6.5	5.5
Age 18-20	8.7	11.9	6.6
Age 21-25	8.1	10.3	6.4
Age 26-30	9.1	12.9	6.7
Age 31-40	6.8	10.1	4.7
Age 40 and over	6.4	-	5.4
Participant rated % of drinks which are combined AEDs in a typical AED session (range: 0-100)	31.0 (25.2)	30.0 (25.9)	31.9 (24.7)
Age 16-17	37.0	35.8	38.8
Age 18-20	34.2	33.1	35.0
Age 21-25	31.4	29.6	33.1
Age 26-30	23.1	20.8	24.9
Age 31-40	27.0	30.9	24.4
Age 40 and over	32.8	-	27.4

\*blank cells had insufficient *n* to calculate.

Table 19 shows the breakdown of alcohol, energy drink, and AED consumption amongst all participants in the past 12 months. Aside from 16-17 year olds, alcohol consumption was consistent across all age groups in the past 12 months. Energy drink consumption was consistent for groups aged between 16 and 30, with approximately two thirds of respondents reporting having consumed energy drinks in the past 12 months. This rate dropped substantially, with only 1 in 4 participants aged 40 and over having consumed energy drinks in the preceding 12 months.

AED consumption was highest amongst participants aged 18-25, with almost half of this age group reporting having consumed AEDs in the past 12 months. One quarter of participants aged 16-17 reported having consumed AEDs in the past 12 months. AED consumption prevalence dropped substantially for participants aged over 30.

*Table 19. Prevalence of alcohol, ED and AED consumption between age groups in the past 12 months.*

Overall prevalence of consumption per each age bracket (%)	Alcohol	ED	AED
<i>Age 16-17</i>	54.3%	69.6%	26.1%
<i>Age 18-20</i>	91.7%	64.6%	45.8%
<i>Age 21-25</i>	92.4%	67.7%	49.6%
<i>Age 26-30</i>	94.4%	62.6%	35.2%
<i>Age 31-40</i>	92.2%	45.0%	18.2%
<i>Age 40 and over</i>	90.6%	23.4%	9.4%

Univariate odds ratios were calculated in an attempt to predict population subgroups more likely to consume 3 or more EDs per typical AED session. Table 20 demonstrates that males and participants aged between 18 and 25 were more likely to consume 3 or more EDs in a typical AED session. Other demographic factors associated with consuming 3 or more EDs in an AED session were being single or casually dating (as opposed to being in a steady relationship), casual employment and being a tertiary student. Participants without tertiary qualifications (including those still studying) were also more likely to consume 3 or more EDs in a typical AED session. Participants who earned \$20,000-\$35,000 per year were most at risk of consuming 3 or more EDs in a typical AED session, perhaps this is conflated by a large proportion of students in this income bracket. Interestingly, odds of high AED use were lower for participants earning less than \$20,000 per annum.

Table 20. Odds ratios of demographic sub-groups more likely to consume 3 AEDs per session<sup>#</sup>

Variable	Odds Ratio	Variable	Odds Ratio
<b>Relationship Status</b>		<b>Gender</b>	
Serious/Stable	1.49	Male	1.89
Not in a relationship	1.67	Female	ref
Casually dating	2.21	<b>Highest Education Completed</b>	
De-facto	ref	Advanced Diploma/Diploma or equiv.	1.16
Married/legal partnership	0.51	Bachelor Level	ref
Divorced	1.26	Certificate/Apprenticeship	0.54
Separated	1.02	Completed HSC/HEC (Year 12 or equiv.)	1.25
Widowed	0*	Honours/Graduate Diploma Level	0.44
<b>Gross Income</b>		PostGrad Degree Level	0.32
\$20,000 or lower	0.80	Year 10 or equivalent	0.60
\$20,001 to \$35,000	ref	Year 8 or below	0*
\$35,001 to \$50,000	0.84	Year 9 or equivalent	0*
\$50,001 to \$65,000	0.45	<b>Employment status</b>	
\$65,001 to \$80,000	0.52	Studying only	1.36
\$80,001, to \$100,000	0.31	Study/work	1.76
More than \$100,000	0.40	Casual	1.62
<b>Age Bracket</b>		Part-time (30hrs or less)	1.09
16-17	1.70	Full-time	ref
18-20	3.74	Unemployed	1.00
21-25	3.80	Self-Employed	0.62
26-30	1.80	Carer	0.85
31-40	ref	Pensioner/retired	0*
40 and over	0.46		

\*n=0 or too low. #: ref= reference category for univariate odds ratio.

Table 21 shows key participant demographic and consumption measures according to geographic location within Sydney, Newcastle or 'Other' NSW Postcode. Overall, prevalence of alcohol consumption in the last 12 months was consistent across all NSW postcodes, but fewer Sydney residents reported consuming EDs and AEDs. "Other" postcodes were those from NSW residents that fell outside of Sydney or Newcastle metropolitan areas.

Table 21. Key consumption and demographic variables according to resident location

Variable	Location				
	Sydney (n=343)	Newcastle (n=755)		Other NSW Postcode (n=669)	
Use in the past 12 months (%)					
Alcohol	89.5%	93.2%		90.4%	
Energy Drinks**	47.1%	62.2%		61.2%	
Combined AEDs**	28.5%	40.9%		39.3%	
	<i>Statistic (SD)</i>	<i>Statistic (SD)</i>	<i>t value (df)</i>	<i>Statistic (SD)</i>	<i>t value (df)</i>
Mean Age of Respondents (yrs)	31.6 (10.3)	24.0 (6.5)	15.425 (1189)**	26.7 (10.2)	7.607 (1120)**
Gender					
Male (%)	37.3%	35.2%		36.5%	
Alcohol Use (std drinks)					
Typical Session	3.8 (3.0)	5.1 (3.6)	6.29 (778.9)**	5.2 (3.9)	6.32 (861.2)**
Max. Session	9.0 (6.4)	11.6 (7.8)	5.80 (758.8)**	11.1 (7.5)	4.715 (756.4)**
Energy Drinks (std energy drink)					
Typical Session	1.2 (0.8)	1.5 (1.2)	2.77 (427.5)*	1.4 (1.0)	2.78 (365.6)*
Max. Session	2.0 (1.7)	2.3 (2.0)	1.63 (622)	2.5 (2.1)	2.58 (350.1)*
AED Usage (AED Sessions)					
Typical Session Alcohol	5.5 (4.6)	6.1 (4.0)	1.38 (431)	5.8 (4.1)	0.62 (395)
Typical Session ED	2.5 (2.6)	3.1 (2.5)	2.13 (431)*	3.1 (2.6)	2.20 (393)*
Max Session Alcohol	7.7 (6.4)	8.7 (6.8)	1.38 (426)	7.9 (6.6)	0.21 (392)
Max Session ED	3.0 (2.6)	4.0 (3.0)	3.18 (212.4)*	3.9 (3.1)	2.87 (227.0)*

Note: The t-tests compare "Newcastle" or "Other Postcode" to "Sydney", which is the baseline variable.

\*sig<0.05  
\*\*sig<0.001

#### **4.3.2.6 Between Groups Comparisons: Alcohol Only versus AED Consumers**

Between groups analysis using independent sample t-tests demonstrated that participants who were AED users consumed alcohol at a significantly higher rate than participants who consumed only alcohol. These results were significant with a strong effect size for typical alcohol sessions ( $M_{\text{ALCONLY}}=3.65$ ,  $SD=2.84$ ,  $M_{\text{AEDUSER}}=6.67$ ,  $SD=3.93$ ;  $t_{(1727)}=-18.523$ ,  $p < 0.001$ ;  $d=-0.891$ ).

T-tests also indicated that participants who were AED users consumed alcohol at a significantly higher rate than participants who consumed only alcohol during maximum reported consumption sessions ( $M_{\text{ALCONLY}}=8.27$ ,  $SD=5.61$ ,  $M_{\text{AEDUSER}}=14.71$ ,  $SD=8.24$ ;  $t_{(1725)}=-19.34$ ,  $p < 0.001$ ;  $d=-0.93$ ).

Further, between groups comparisons indicated that AED users reported significantly younger age of “first drink” of alcohol ( $M_{\text{ALCONLY}}=16.09$ ,  $SD=2.30$ ,  $M_{\text{AEDUSER}}=15.72$ ,  $SD=1.59$ ;  $t_{(1732)}=3.69$ ,  $p=0.005$ ). However, the effect size of this relationship was weak ( $d=0.177$ ).

AUDIT-C scores and risk classifications were calculated for all participants who were alcohol consumers. 2x2 chi-square comparisons indicated a significantly greater proportion of AED users were classified as high risk alcohol users, compared to respondents who consumed alcohol alone ( $\chi^2=102.17$ ,  $p < 0.001$ ). Further, participants who were classified as high risk by the AUDIT-C were also significantly more likely to have consumed more than 2 energy drinks in a single session in the past 12 months ( $\chi^2=53.54$ ,  $p=0.001$ ).

#### **4.3.2.7 Within Groups Comparisons: AED Consumers**

Within subject comparison analyses ( $n=698$ ) indicated that AED users consumed significantly more alcohol during typical “alcohol only” sessions than during typical “AED” sessions. On average, AED users consumed 6.7 ( $SD=4.0$ ) drinks during alcohol only sessions, compared to 6.0 ( $SD=4.2$ ) during typical AED sessions ( $t_{(698)}=4.734$ ,  $p < 0.001$ ). The effect size was weak for this relationship ( $d=0.182$ ). Further, when participants were asked to report on maximum consumption amounts, within subject comparison analyses ( $n=693$ ) indicated that AED users consumed significantly more alcohol during maximum “alcohol only” sessions than during maximum “AED” sessions. On average, AED users consumed 14.7 ( $SD=8.3$ ) drinks during “maximum” alcohol only sessions, compared to 8.3 ( $SD=6.7$ ) during maximum AED sessions ( $t_{(692)}=24.164$ ,  $p < 0.001$ ). The effect size for this relationship was very strong ( $d=0.860$ ).

Within subject comparison analyses ( $n=689$ ) indicated that AED users consumed significantly more energy drinks during typical “AED” sessions than when consuming energy drinks unmixed with alcohol. On average, AED users consumed 1.5 ( $SD=1.1$ ) standard energy drinks during ED only sessions, compared to 3.0 ( $SD=2.6$ ) during typical AED sessions ( $t_{(688)}=-16.207$ ,  $p < 0.001$ ). The effect size was very strong for this relationship ( $d=-0.782$ ). This pattern of energy drink consumption was also reflected in “maximum” reported ED consumption figures. On average, AED users consumed 2.5 ( $SD=2.2$ ) standard energy drinks during “maximum” ED only sessions, compared to 3.8 ( $SD=3.1$ ) during maximum AED sessions ( $t_{(691)}=-10.540$ ,  $p < 0.001$ ). The effect size for this relationship was moderate ( $d=-0.486$ ).

Male AED users demonstrated higher rates of both alcohol and energy drinks for typical and maximum sessions when compared with females. On average, male AED users consumed 7.4 (SD=4.9) alcoholic drinks during “typical” AED sessions, compared to 4.9 (SD=3.2) for females ( $t_{(718)}=8.450$ ,  $p = <0.001$ ). The effect size for this relationship was moderate ( $d= 0.617$ ). Further, during “maximum” AED sessions, male AED users consumed 10.9 (SD=8.0) alcoholic drinks, compared to 6.3 (SD=4.7) for females ( $t_{(710)}=9.558$ ,  $p = <0.001$ ). The effect size for this relationship was moderate/strong ( $d= 0.696$ ). However, the proportion of drinks classified as AEDs during typical sessions was approximately 1 in 3 for both male and female AED users.

#### 4.3.2.7 Premixed AED Use

In total  $n=463$  respondents (24.0%) of the sample reported that they had consumed pre-mixed alcoholic energy drinks (PMIXAED) in the past 12 months, but did so irregularly (Figure 19). Forty seven percent of participants who reported that they had not consumed PMIXAED had hand-mixed AEDs. Of participants who consumed PMIXAED, 87.9% had also hand-mixed AEDs in the past 12 months.

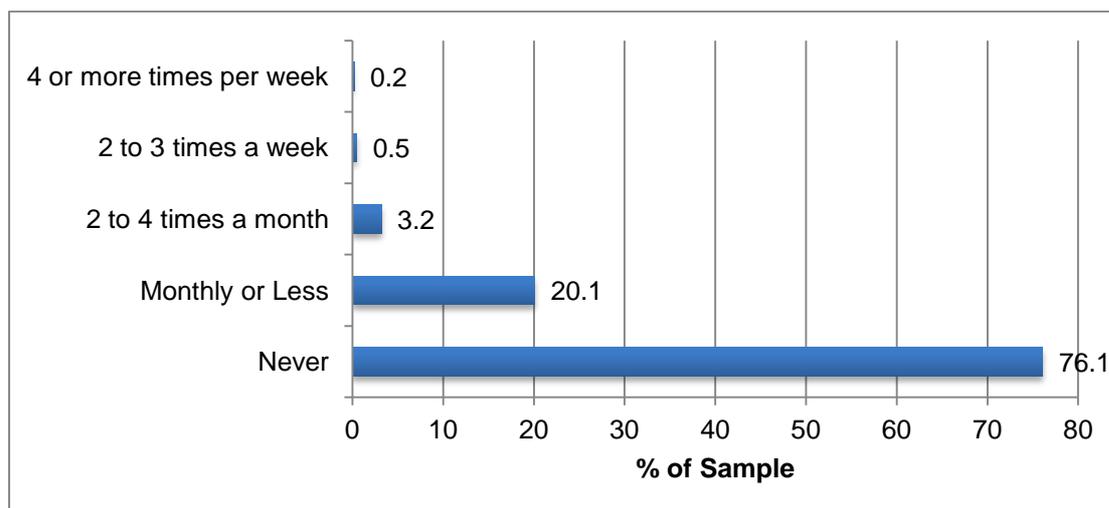


Figure 19. Frequency of PMIXAED use in past 12 months

In a typical PMIXAED session, most users consumed fewer PMIXAED drinks than “other” alcoholic drinks. PMIXAED users reported a mean of 2.8 PMIXAED drinks during a typical session (SD=2.4), compared to a mean of 5.6 “other alcoholic drinks” (SD=4.6).

#### 4.3.2.8 AED Users: Self Reported AED Consumption Methods

AED users were asked to report their preferred method for combining AEDs. The majority (85.2%) of AED users hand mixed energy drinks with a spirit, using the energy drink as a mixer. The other popular form of consumption was ‘Bombs’ (53.1%), whereby a shot of spirit is dropped into a glass of energy drink and consumed rapidly (Figure 20).

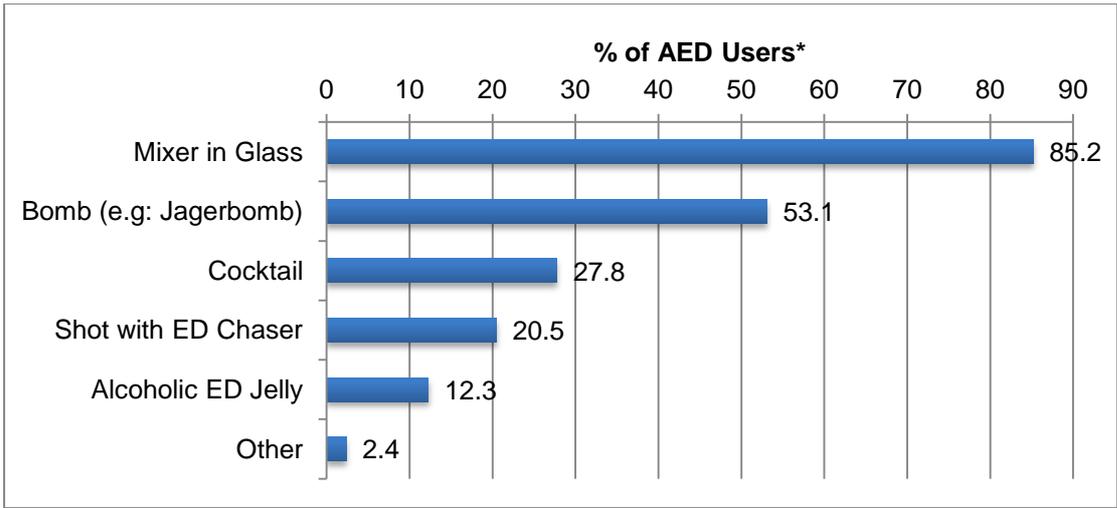


Figure 20. AED consumption methods reported by AED Users: Frequency (% of AED users)

\*Users were able to select more than one response.

**4.3.2.9 Consumption Scenarios: Comparison of Alcohol, ED and AED users**

The figures below demonstrate the typical contexts in which energy drinks, alcohol or AEDs were reportedly consumed. Consumption of alcohol “alone” (not with energy drinks) occurred in a wide variety of scenarios, but most frequently at home alone, with friends/family, at parties, in licensed venues, and with meals (Figure 21). Energy drinks (not mixed with alcohol) were consumed most frequently prior to/during work/school and university, and at parties. EDs were consumed more frequently in private residences than in licensed venues (Figure 22). AEDs were consumed in a more limited number of contexts than alcohol alone; most often in licensed venues, at festivals and at private residences with friends and family (Figure 23).

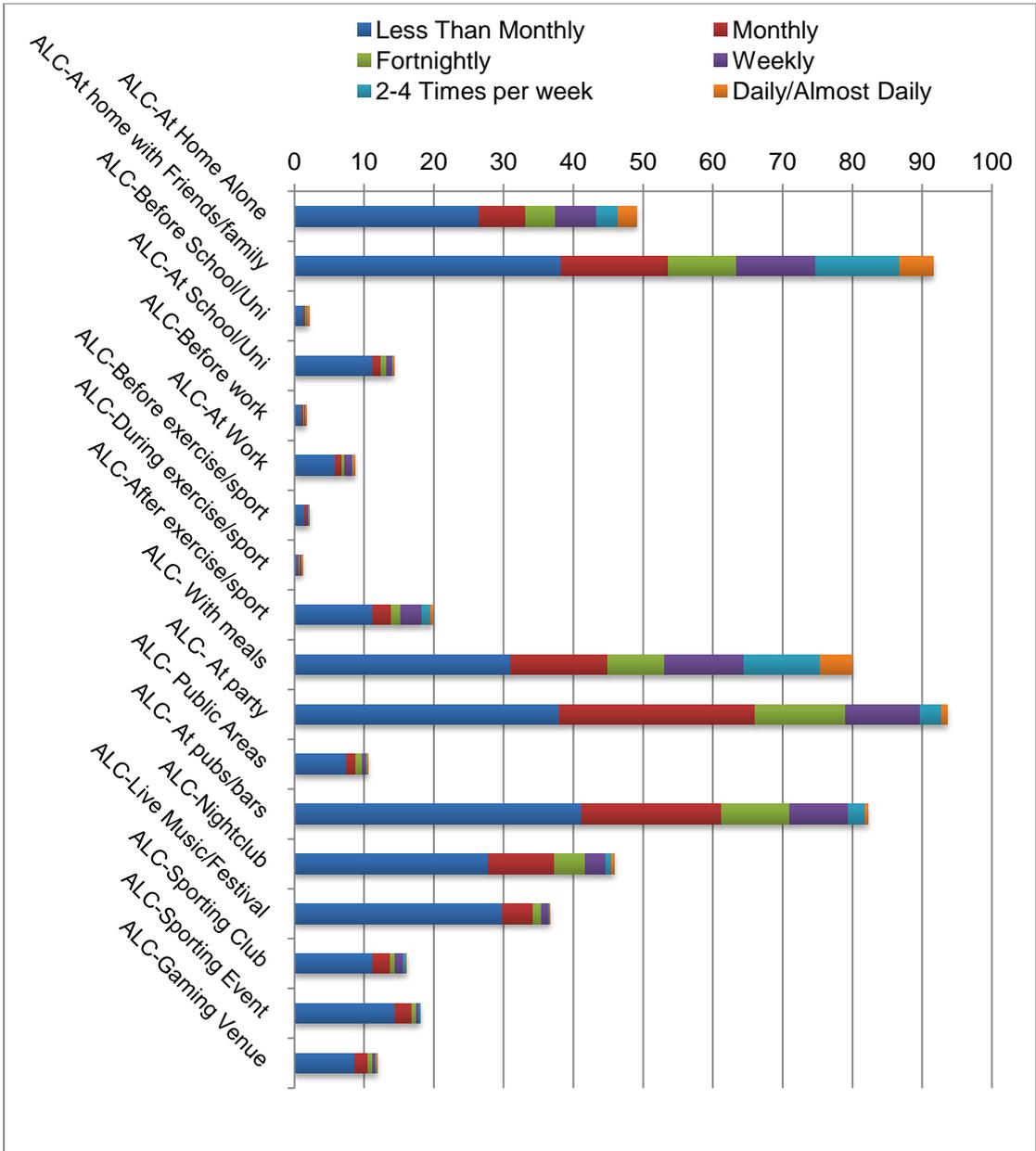


Figure 21. ALCOHOL ONLY USERS: Frequency of alcohol use in consumption scenarios (%)

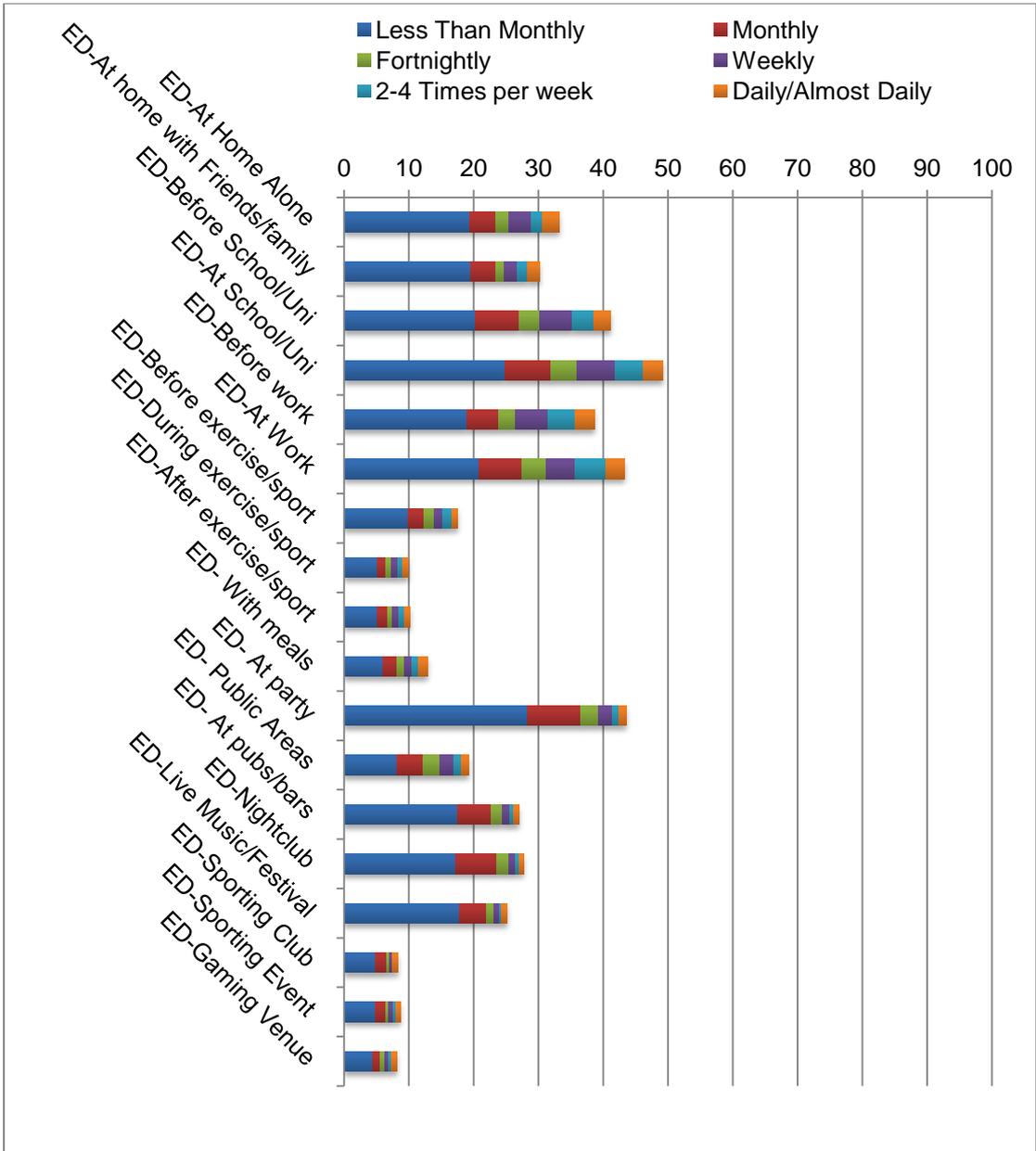


Figure 22. ED USERS: Frequency of ED use in consumption scenarios (%)

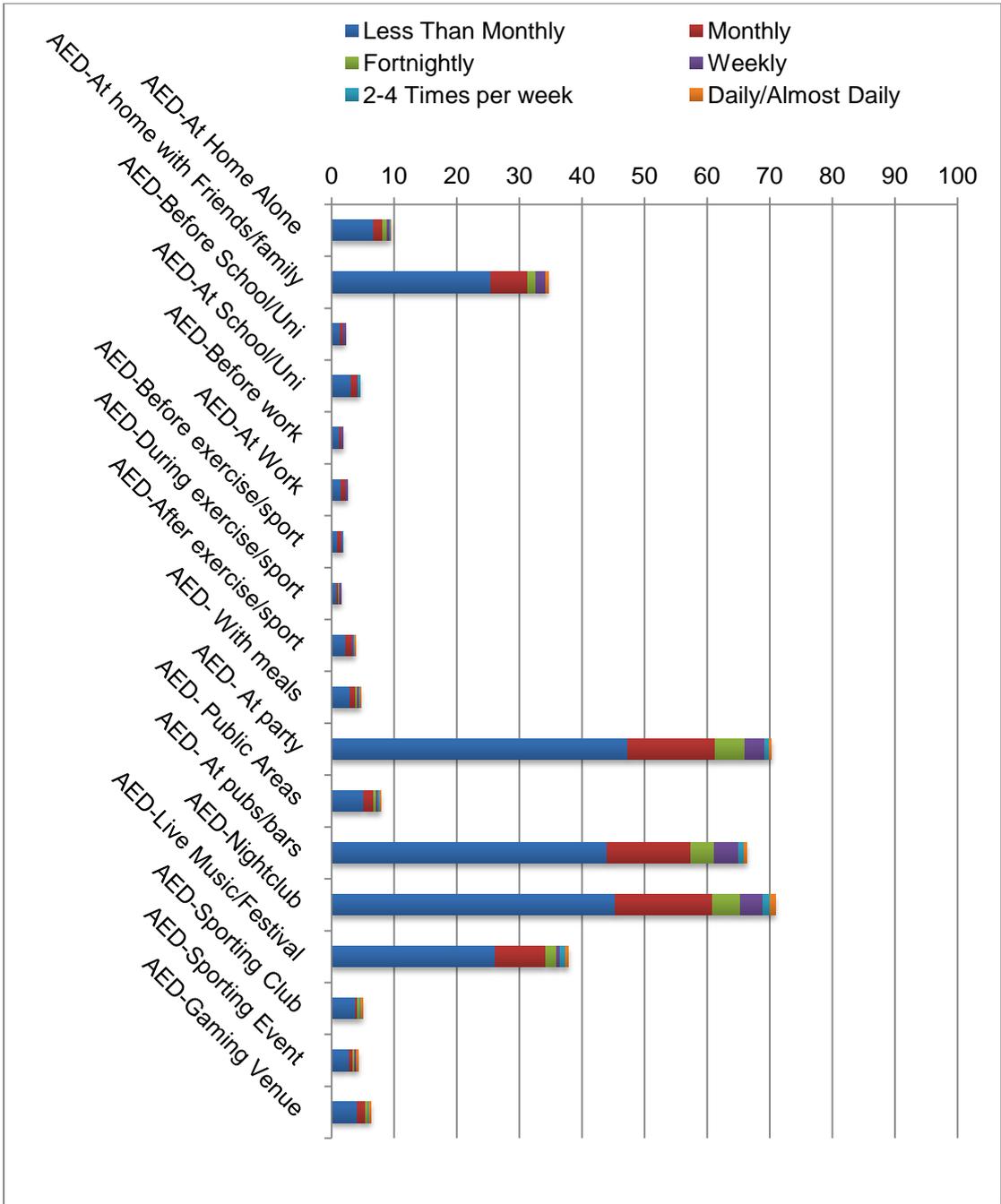


Figure 23. AED USERS: Frequency of AED use in consumption scenarios (%)

#### 4.3.2.10 Knowledge of Guidelines around Maximum Daily Consumption of EDs

AED users were asked to report upon their knowledge of the current Australian guidelines for energy drinks in terms of the maximum amount of energy drinks recommended to be consumed in one day. Participants were supplied with a visual reference to assist them in identifying the correct classification for a “standard” energy drink.

Overall, 40.5% of AED users ( $n=296$ ) reported the correct response of 2 “standard energy drinks” per day. Other respondents reported incorrect numbers or “don’t know,” indicating that knowledge of safe energy drink consumption levels is low.

Younger participants and participants who were current ED users were more likely to be aware of current energy drink consumption guidelines (Figure 24). Over a third of ED using participants aged 16-17 correctly identified current guidelines, increasing to 43.6% of ED users aged 21-25. Participants aged 40 and over recorded the lowest levels of correct identification of guidelines.

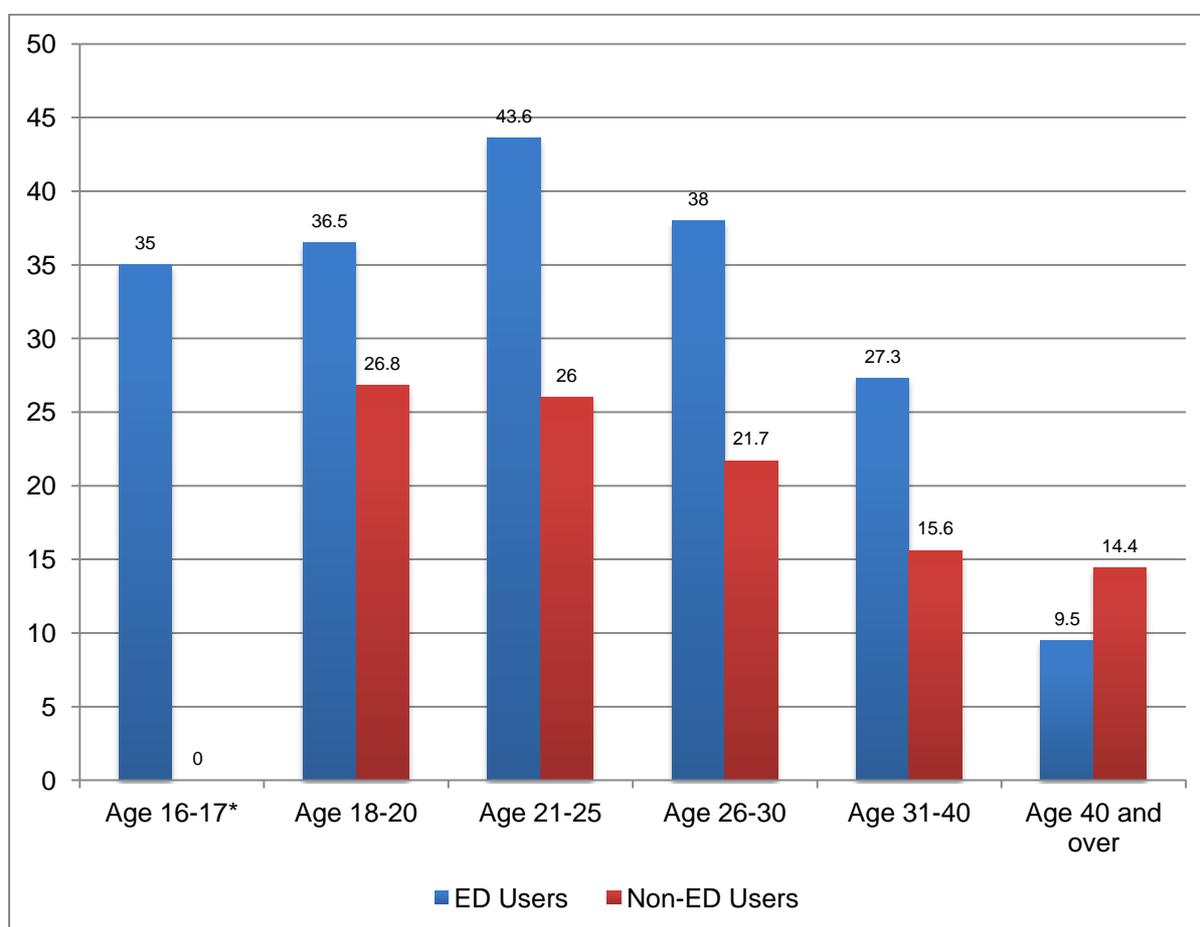


Figure 24. Awareness of current daily energy ED guidelines: percentage of correct response according to age and consumer status (%)

However, knowledge of correct consumption guidelines was not significantly related to energy drink use. An independent sample t-test comparing those who correctly identified guidelines to those who did not found that levels of unmixed energy drink use not significantly different between the groups ( $M_{\text{GUIDELINES-CORRECT}}=1.55$ ,  $SD=1.14$ ,  $M_{\text{GUIDELINES-INCORRECT}}=1.40$ ,  $SD=1.024$ ;  $t_{(695)}=-1.85$ ,  $p=0.65$ ).

This finding extended to energy drink consumption during AED sessions. An independent sample t-test comparing those who correctly identified the guideline to those who did not found that levels of energy drink use during a typical AED session were not significantly different between the groups ( $M_{\text{GUIDELINES-CORRECT}}=2.96$ ,  $SD=2.13$ ,  $M_{\text{GUIDELINES-INCORRECT}}=3.02$ ,  $SD=2.82$ ;  $t_{(718)}=-0.313$ ,  $p=0.754$ ).

#### 4.3.2.11 Illicit Substance Use

AED users consumed more illicit substances than participants who only consumed alcohol. As demonstrated in Figure 25, AED users consumed illicit substances at between 3 to 6 times the rates of alcohol only users.

However, as shown in Figure 26, within subjects analysis indicates that AED users consumed illicit drugs at approximately 2 to 3 times higher rates during “alcohol only” sessions compared to during AED sessions.

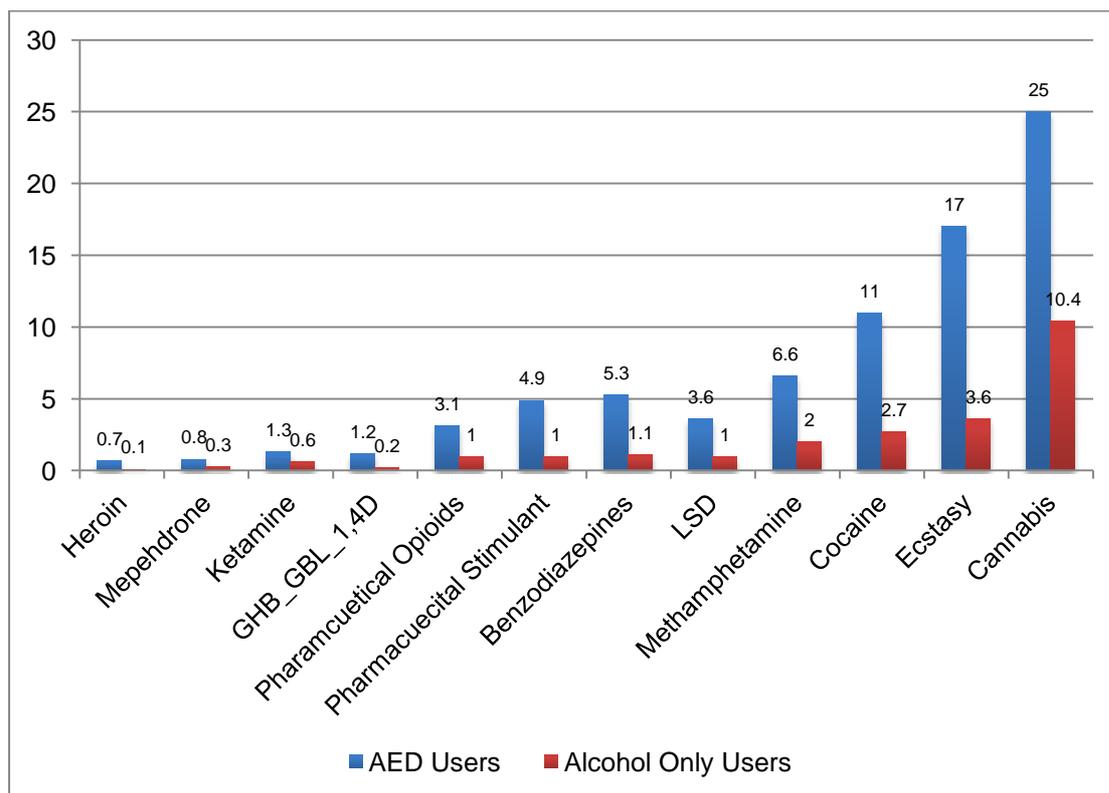


Figure 25. Between groups illicit substance use – Frequency of illicit substance use during alcohol only sessions by ALCOHOL ONLY users vs. AED users (%)

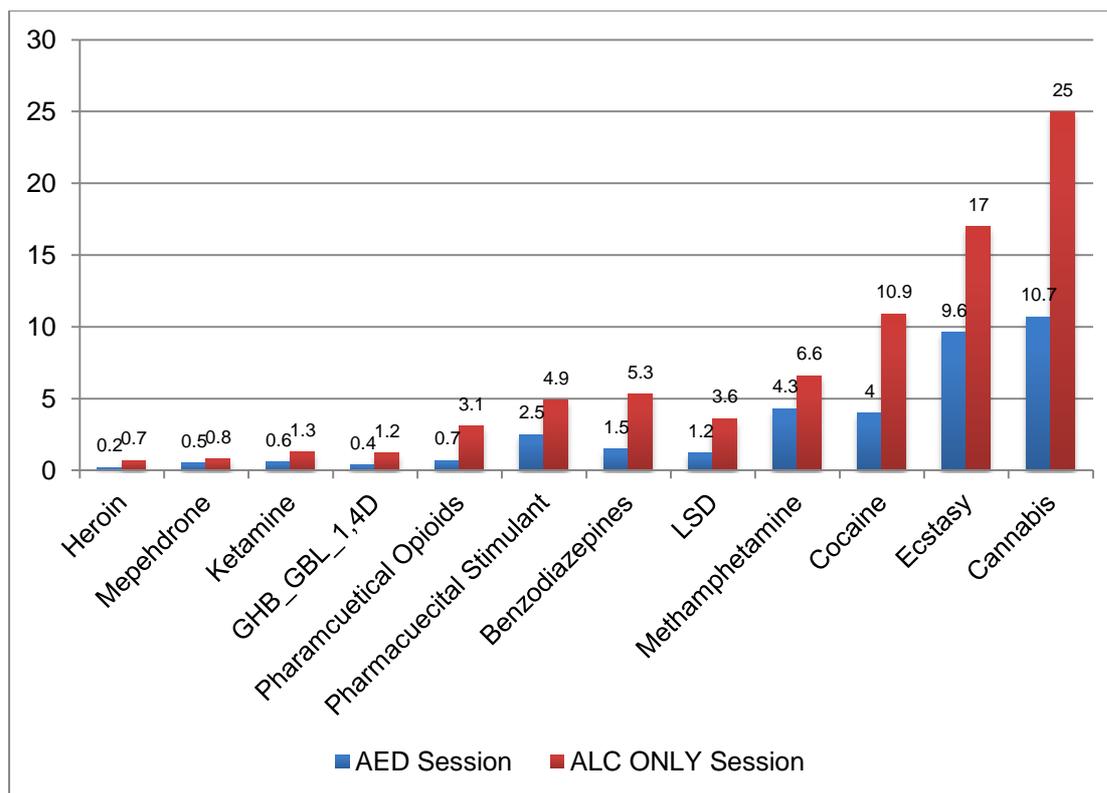


Figure 26. Within group illicit substance use – Frequency of illicit substance use during ALCOHOL ONLY sessions vs. AED sessions ( % AED users only)

AED users were invited to report whether they had changed their substance use within the past 12 months due to their AED consumption, and were able to respond that it had increased/decreased, started/stopped, remained unchanged, or that they had not consumed the substance at all.

Fluctuation in illicit drug use behaviour as a result of AED use was negligible. Thirteen percent of AED users reported an overall increase in alcohol use, and 5.7% of participants reported an increase in tobacco consumption, which they attributed to having commenced AED use (Table 22). However this was not an objective consumption measure and may be more vulnerable to recall bias than other consumption items.

Table 22. Self-rated change in substance use behaviour due to AED consumption

	Stopped	Decreased	Unchanged	Increased	Started	N/A
Alcohol	0.5	2.7	51.8	12.6	0.4	30.8
Tobacco	1.0	0.8	19.4	5.3	0.4	71.3
Cannabis	1.1	0.8	17.8	1.6	0.3	77.0
Ecstasy	0.7	0.8	14.1	0.8	0.7	81.4
Cocaine	0.4	0.4	11.1	0.4	0.1	86.0
Methamphetamine	0.5	0.1	9.3	0.3	0.1	88.4
Benzodiazepines	Nil	0.3	7.7	0.4	0.4	89.9
LSD	0.1	0.1	8.3	0.1	Nil	89.9
Pharmaceutical Stimulant	0.3	0.1	8.1	0.1	0.1	90.0
Pharmaceutical Opioids	Nil	0.3	6.6	0.4	Nil	91.2
Mephedrone	0.1	Nil	6.3	Nil	0.1	91.5
Heroin	Nil	0.1	6.4	0.1	Nil	91.8
GHB_GBL_1,4D	0.1	Nil	6.4	0.1	0.1	91.9
Ketamine	0.1	Nil	6.7	Nil	0.1	91.8

\*1.4% of cases were missing data for this item

#### 4.3.2.12 Motivations for Alcohol and AED Use

Participants were asked to report their motivations for using alcohol and these motivations did not vary substantially among alcohol only users and AED users. For both alcohol only users and AED users, the most commonly reported motivations for alcohol use were to celebrate, to be sociable, to relax, to make gatherings enjoyable, to have fun, because it is customary at gatherings, because they like the feeling, to feel good and for more confidence.

The most frequently reported motivations for AED use were specific to participants' desire for energy/endurance, compensating for lack of sleep, and favouring the taste. This is consistent with motivations of use reported in international surveys. Issues of price and availability were also comparatively high. Motivations relating to desired levels of intoxication and mimicking the effect of illicit stimulants were relatively infrequent (Figure 27).

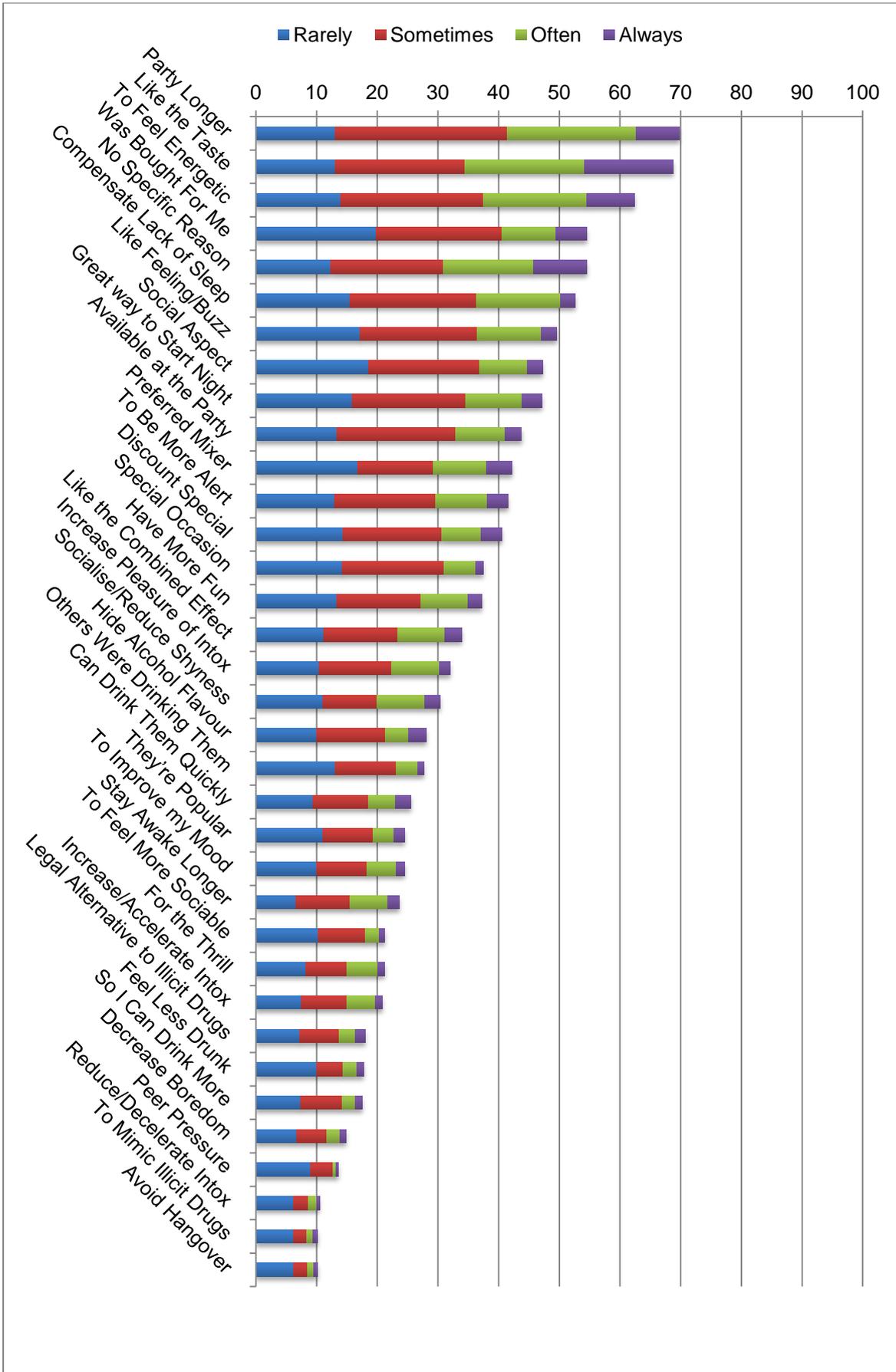


Figure 27. Motivations for AED use - AED users (% Frequency of motivation)

#### 4.3.2.13 Experience of Side Effects: Comparison of Alcohol, Energy Drink and AED users

Participants were asked to report upon the frequency of side effects experienced during alcohol, ED and AED use. These results are presented in figures 28-35 below.

**Alcohol only users** reported decreased co-ordination, fatigue, dizziness, slurred speech, headache, nausea and walking difficulties as the most common *immediate* side effects of alcohol use. These symptoms were experienced by over 30% of the sample in the last 12 months (Figure 28). In the *days following* alcohol use, alcohol users reported headache, fatigue, nausea, low sense of wellbeing, gastrointestinal issues, physical weakness and vomiting as the most commonly occurring side effects of alcohol use (Figure 29).

**Energy drink users** reported heart racing and palpitations, energy fluctuations, insomnia, fidgeting, fast speech and agitation as the most common *immediate* side effects of energy drink use, experienced by over 20% of the sample in the past 12 months (Figure 30). Experience of side effects in the days following EDs was relatively low when compared to immediate effects of ED use, the use of alcohol alone, or AED use. In *days following* energy drink use, ED users reported insomnia, fatigue, heart racing, gastrointestinal issues, visual disturbances and heart palpitations as the most commonly occurring side effects of ED use in the past 12 months. However, these were experienced by less than 15% of ED users, and the majority of symptoms were experienced by 5% or less (Figure 31).

**AED users** experienced a wider variety of relatively frequent *immediate* side effects compared to alcohol only users, with 14 of the available options experienced by over a quarter of the sample in the last 12 months. AED users reported heart racing and palpitations, energy fluctuations, insomnia, fidgeting, fast speech, agitation, visual disturbances and breathing difficulties as the most common immediate side effects of AED use (Figure 32). Many of these side effects were similar with those most commonly reported by ED only users, though overall prevalence amongst AED users was higher. Immediate side effects experienced increased relative to ED use, and were most commonly reported after five AEDs (Figure 33). Racing heart was consistently the most commonly reported immediate side effect at all consumption levels, increasing from 43% at one ED to 70% at five EDs. Other frequently reported symptoms were nausea, fluctuating energy and insomnia. At higher consumption levels, speech effects such as slurred speech and increased rate of speech became more common.

The most commonly reported side effect experienced by AED users in *days following* was “visual disturbances” with over 40% of AED users reporting this experience within the past 12 months (Figure 34). Other commonly experienced symptoms reflected those reported by participants in days following a typical “alcohol only” session, however overall prevalence was higher and occurrence of heart racing/palpitations was approximately doubled. The experience of side effects in the days following AED use were most commonly reported after consumption of between 4-6 EDs (Figure 35). Among those who typically consumed five EDs and above, symptoms of nausea and fatigue were replaced with symptoms such as breathing difficulties, gastrointestinal issues, racing heart and heart palpitations. Visual disturbances were the most frequently reported side effect experienced in the past 12 months at all levels of EDs, increasing from 33% after one ED to 55% after six AEDs.

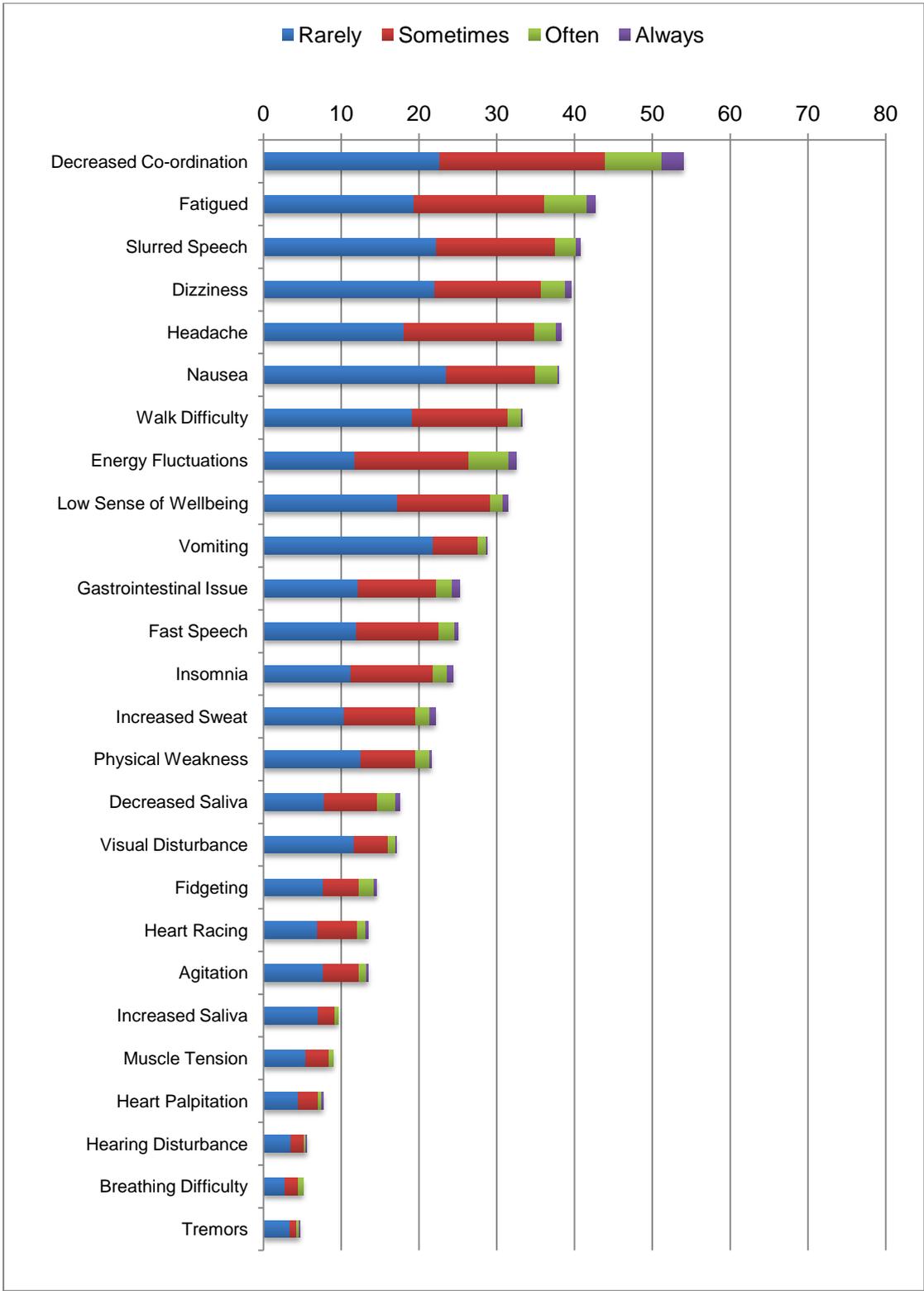


Figure 28. Frequency (%) of immediate side effects experienced by ALCOHOL ONLY users

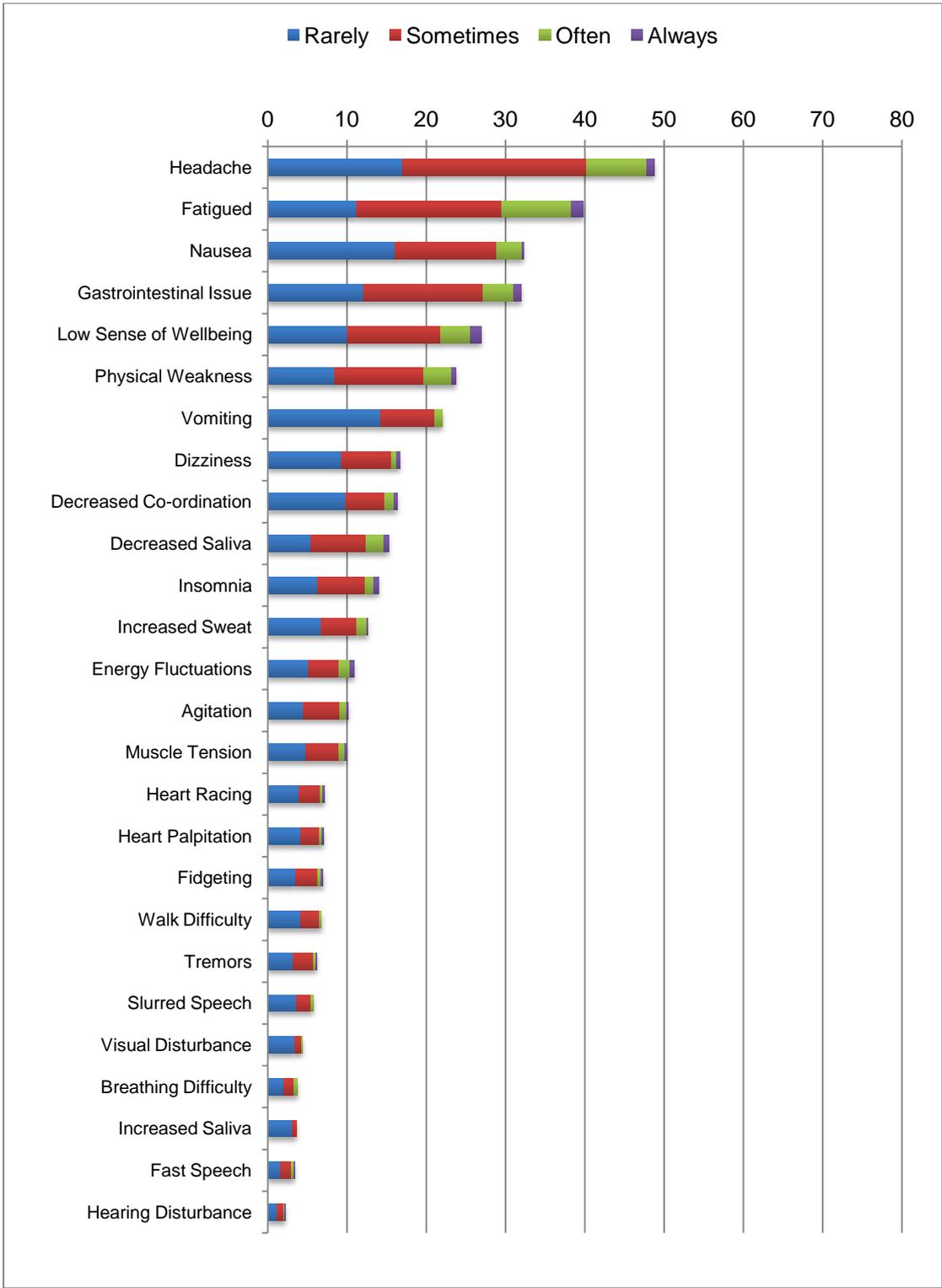


Figure 29. Frequency (%) of side effects experienced in the days following alcohol use by ALCOHOL ONLY users

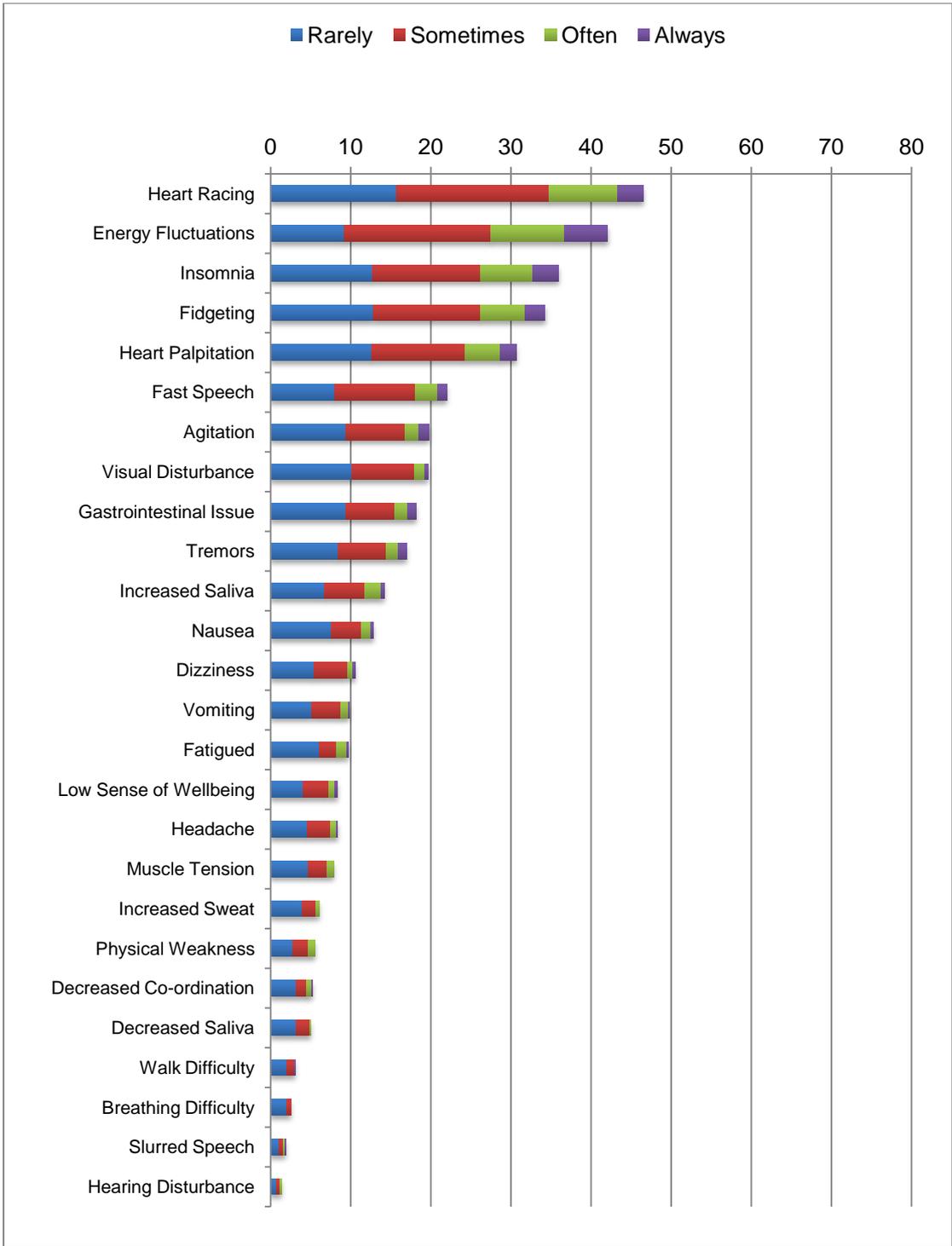


Figure 30. Frequency (%) of immediate side effects experienced by ED users

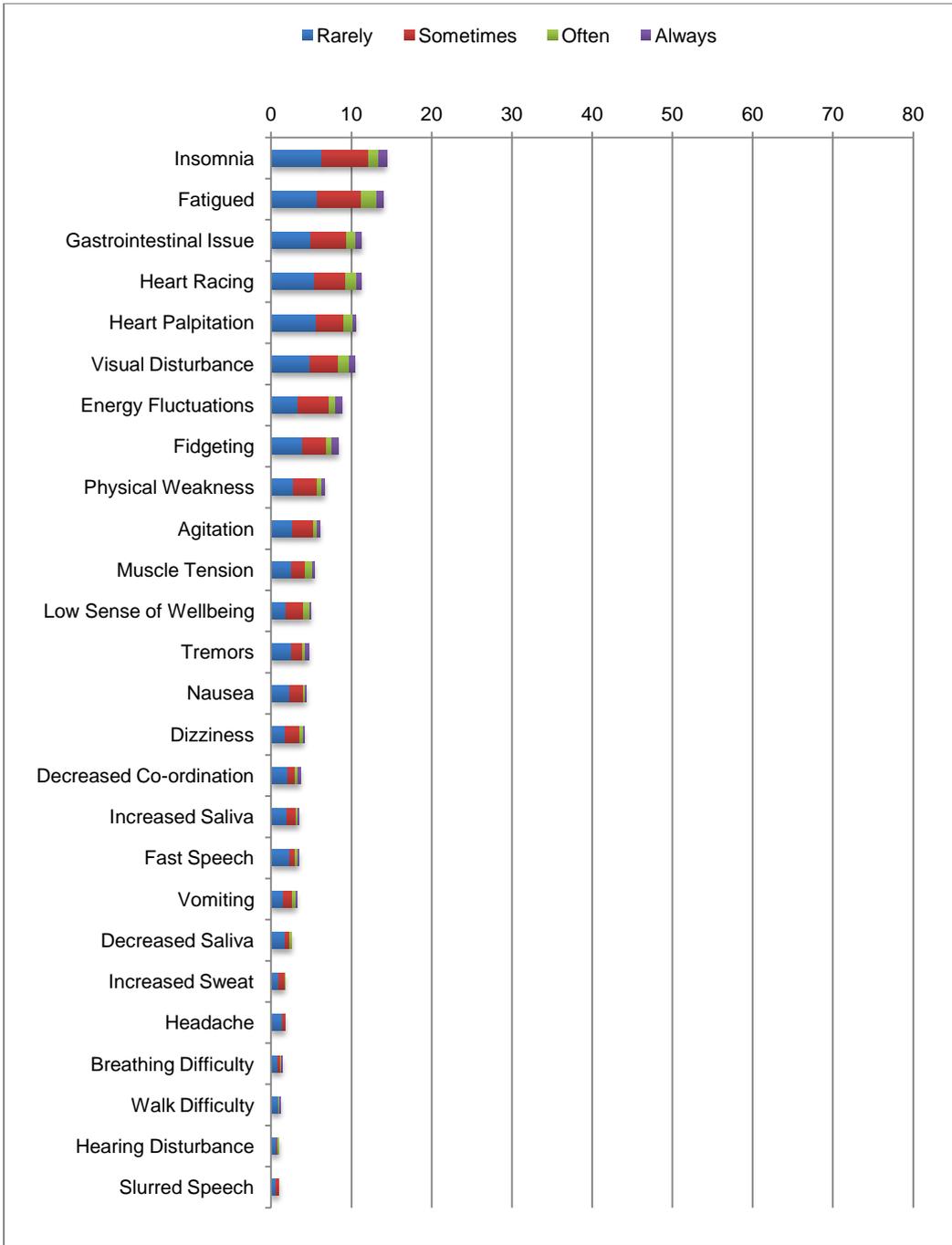


Figure 31. Frequency (%) of side effects experienced in days following ED use

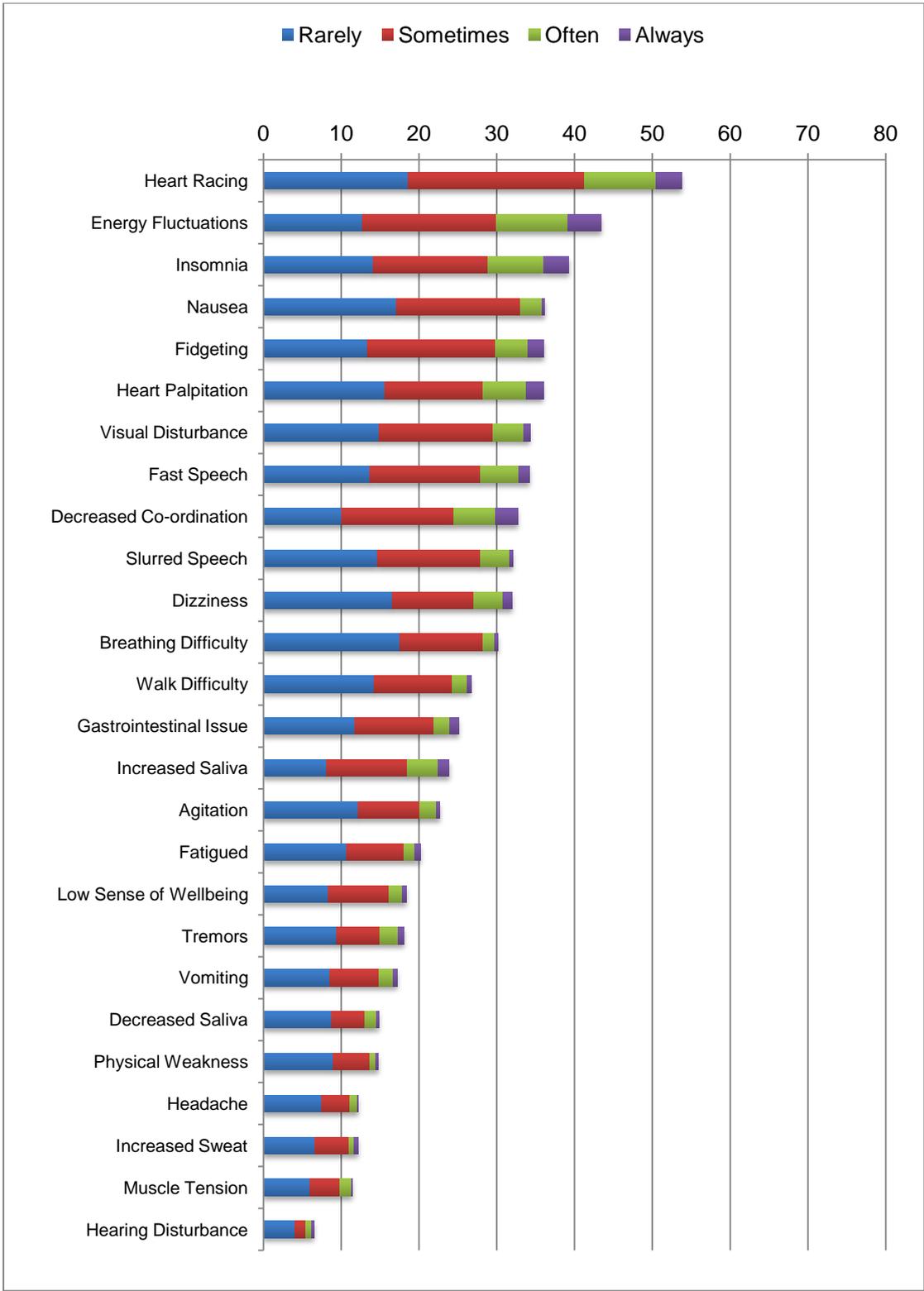


Figure 32. Frequency (%) of immediate side effects experienced during AED use

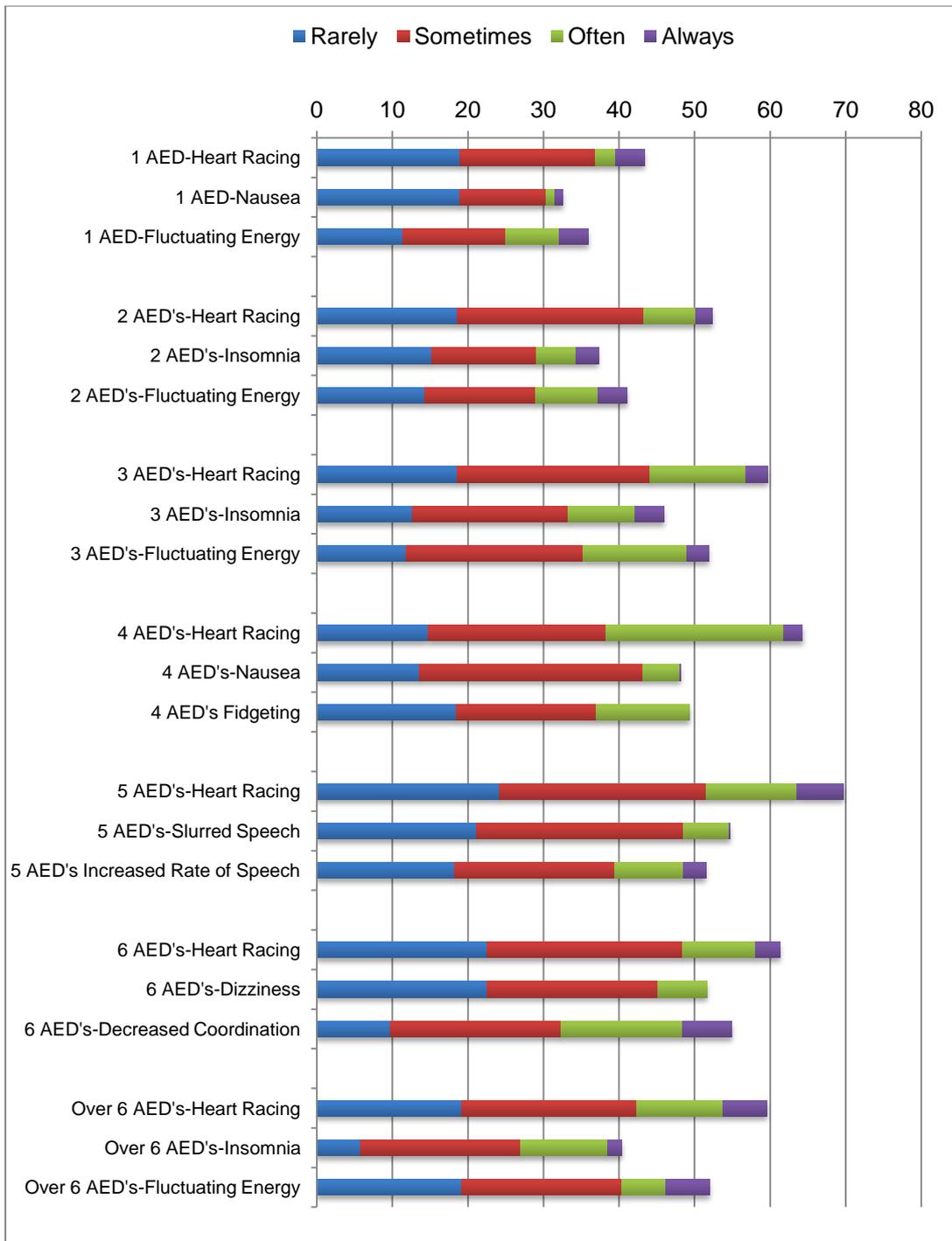


Figure 33. Side effects experienced immediately after AED consumption, aggregated according to typical number of EDs during AED session (%)

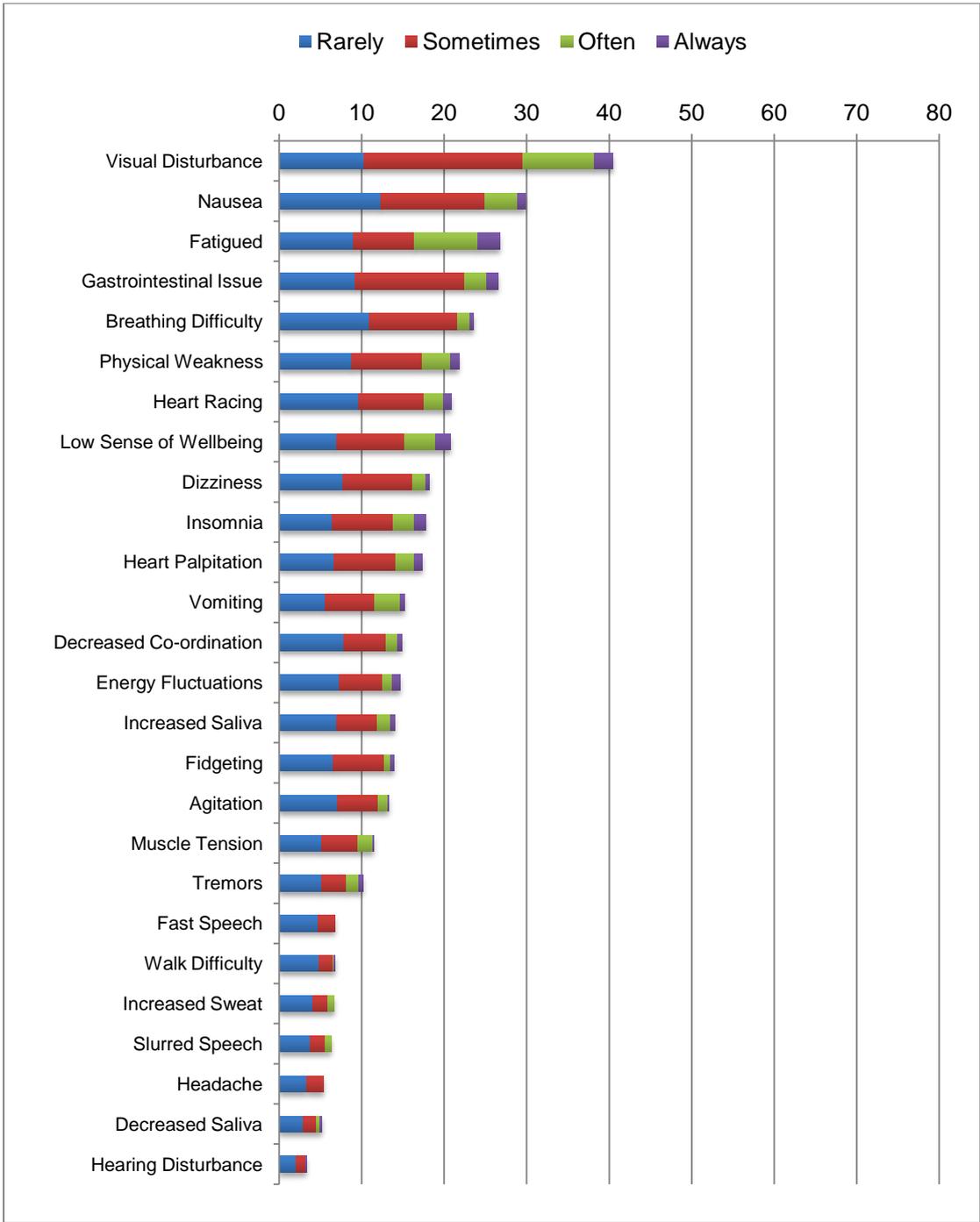


Figure 34. Frequency (%) of side effects experienced in days following AED use

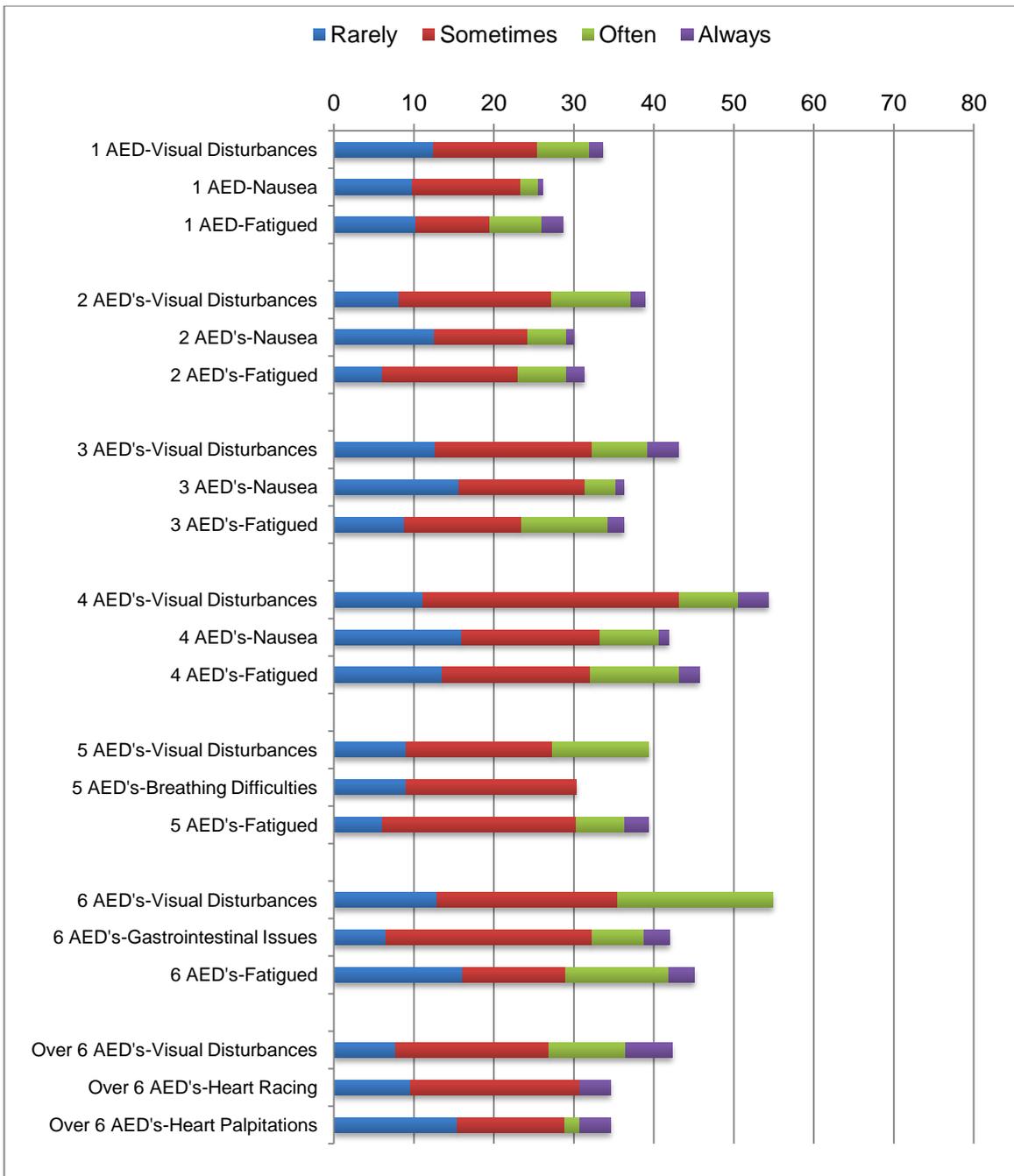


Figure 35. Side effects experienced in days following AED use, aggregated according to typical number of EDs during AED session (%)

### **AED Side-effects Summary**

In summary, the most commonly reported side effects experienced by AED users during sessions of AED use were racing heart/heart palpitations, insomnia, energy fluctuations and nausea. These side effects increased with increasing AED dose, and were most commonly reported after 5 AEDs. Racing heart was consistently the most commonly reported side effect at all consumption levels, increasing from 43% after 1 AED to 70% after 5 AEDs. However, at higher consumption levels, other side effects such as slurred speech, increased rate of speech, dizziness and decreased coordination became more common.

The most commonly reported 'after' effects (in the days following) of AED use were visual disturbances, nausea and fatigue. These side effects increased with increasing AED dose, and were most commonly reported after consumption of between 4-6 AEDs. Visual disturbances were the most commonly reported 'after' effect of AED use at all consumption levels, but at five AEDs and above, side-effects such as nausea and fatigue were replaced with side-effects such as breathing difficulties, gastrointestinal issues, racing heart and heart palpitations.

### **Reasons for Not Consuming AEDs**

Of participants who reported not consuming AEDs in the past 12 months, 60.7% ( $n=247$ ) had never consumed an AED. Reasons for avoiding AED consumption use are displayed below (Table 23). Overall, most ( $n=289$ ; 71.0%) non-AED users reported that they would not consider combining AEDs in the future.

Physical health concerns were the most commonly reported reason for participants avoiding AED consumption. Other popular reasons included concerns about weight/sugar content, sleep/restlessness issues, and patrons not attending nightlife areas as frequently as they had in the past. Reasons such as experiencing aggression, agitation and finding alternate stimulants were the least commonly reported.

Table 23. AED Users: Self-reported reasons for not consuming AEDs within past 12 months

	N/A	Don't Know	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree/ Disagree	Slightly Agree	Agree	Strongly Agree
Physical Health Concern/s	19.9	2.9	6.4	4.9	1.0	5.9	9.3	18.2	27.5
Existing Med. Condition	59.5	2.7	13.0	6.4	-	6.1	1.5	2.7	3.9
Can't Drink Alcohol - Health Reasons	60.0	2.7	13.8	7.9	0.2	4.4	1.2	1.5	4.4
Pregnant/Plan for Pregnancy	62.4	2.0	15.0	7.1	-	4.7	1.0	0.5	2.9
Get Too Intoxicated	45.5	10.1	14.5	9.1	0.5	8.8	2.0	2.9	2.2
Don't get Intox Enough	46.9	7.9	17.7	10.8	1.0	7.9	0.2	2.2	0.5
Increase Hangover	44.5	10.3	13.5	6.9	0.5	8.1	3.2	4.9	2.9
Not Going Out As Much	32.3	2.9	10.3	5.2	-	7.1	8.8	14.5	14.5
Negative Impact on Work/Study	37.6	4.9	16.7	8.8	0.5	7.6	4.2	5.9	8.8
Weight/carbohydrate concerns	33.4	2.2	14.3	6.9	0.5	5.7	10.6	8.6	13.3
Dietary Requirements	45.2	3.7	15.5	9.1	0.5	7.4	3.9	3.7	6.4
Caffeine Sensitivity	42.3	2.9	16.7	8.8	1.2	7.6	4.2	3.7	7.6
Prior Negative ED experience	42.3	3.4	17.0	9.1	2.0	8.1	3.2	3.7	6.4
Anxious Response to ED	43.2	4.9	18.4	10.3	1.2	7.4	3.7	2.7	3.2
Aggressiveness	44.2	4.9	21.4	11.3	1.2	7.4	1.2	1.2	2.5
Became Agitated	43.2	4.9	20.1	11.3	1.7	7.1	2.7	2.2	2.2
Replaced with Alternate Stimulant	47.2	4.2	21.6	10.8	0.7	6.6	2.2	0.5	1.2
Unwanted Reaction to Stimulant	41.5	5.7	19.2	9.1	1.2	7.1	4.2	4.2	3.2
Sleep/Restlessness Problem	36.4	4.7	16.2	5.9	2.2	5.7	7.6	8.4	8.4
AED Drink Price	38.6	4.7	16.0	7.9	0.7	9.1	7.9	4.4	6.4
Dislike Taste	33.7	4.7	12.5	10.6	1.2	6.1	7.4	7.1	11.8

\*Blank cells had 0 respondents. \*Approximately 4.5% of cases were missing data for these items

#### 4.3.2.14 Involvement in Risk Taking Behaviours and Aggression

Between groups comparisons indicate that AED users reported a higher proportion of having had any involvement in aggressive incidents than those who consumed alcohol only ( $\chi^2=35.899$ ,  $p<0.001$ ) (Figure 36).

Compared to alcohol only users, AED users engaged in aggression more frequently with strangers, close friends and venue security. This trend likely reflects the pattern of AEDs typically being consumed most frequently in licensed venues, at festivals and at parties.

Alcohol only users reported a higher frequency of aggression involving partners and AED users reported higher frequency of aggression involving friends, acquaintances, strangers and security staff (Figure 37).

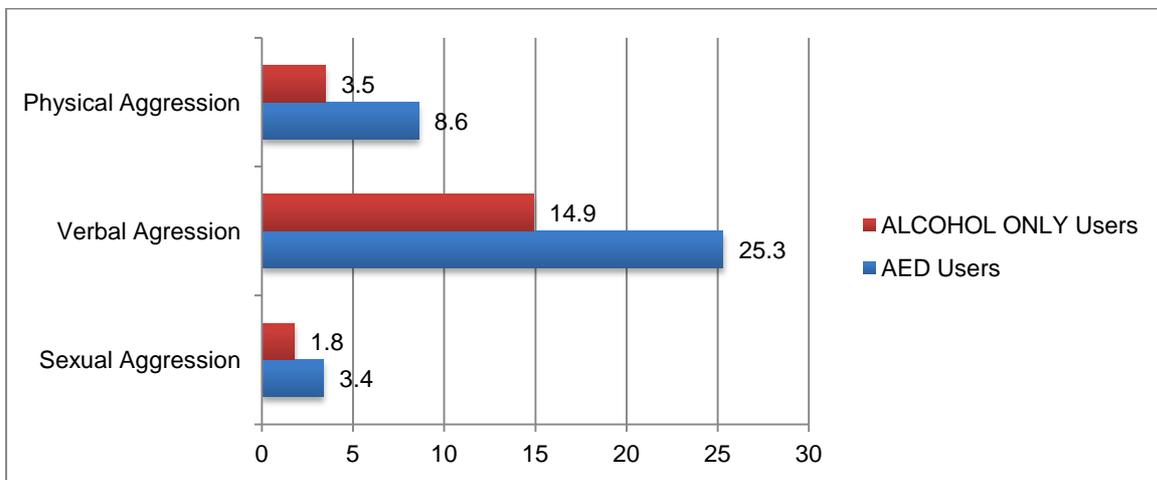


Figure 36. Between groups analysis: Involvement in physical, verbal or sexual aggression in the past 12 months – ALCOHOL ONLY users vs. AED users (%)

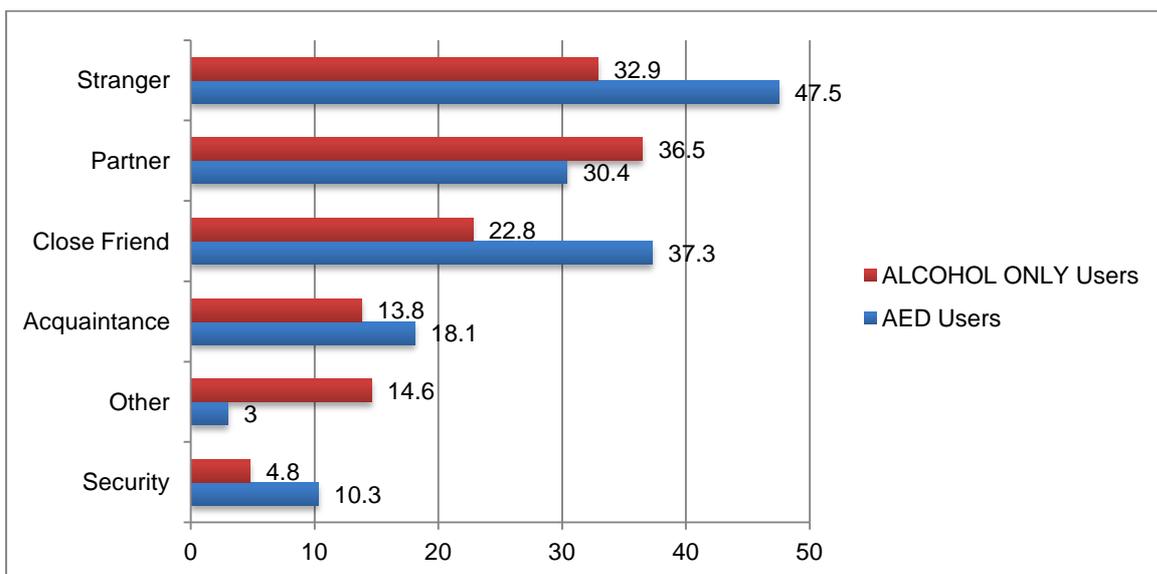


Figure 37. Between groups analysis: Other persons involved in most recent aggressive incident- ALCOHOL ONLY users vs. AED users (%)

Involvement in specific risk taking behaviours is demonstrated in Figure 38. Overall, participants who reported AED use were involved in between 2 to 4 times the number of self-reported risk taking behaviours in the past 12 months.

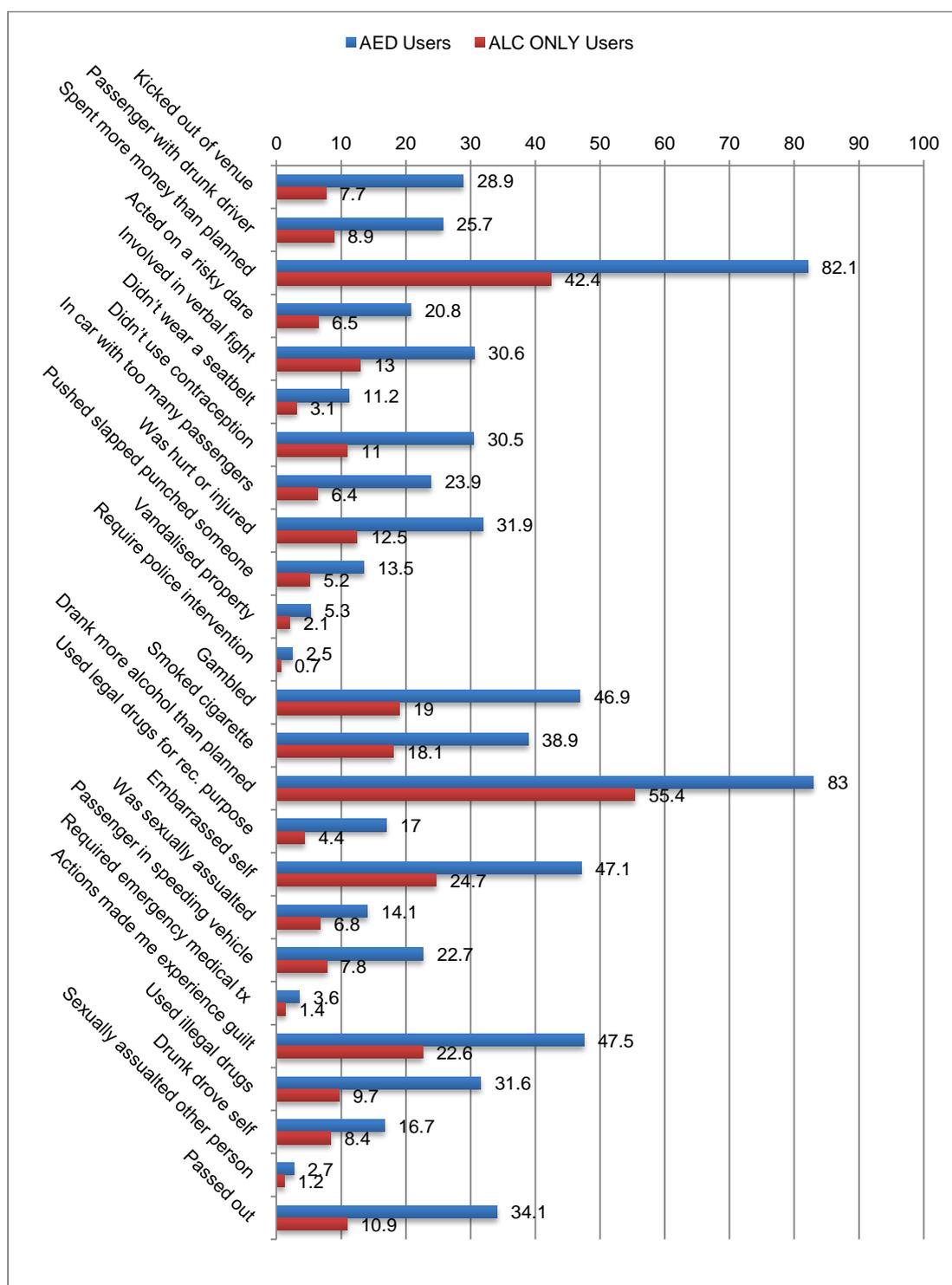


Figure 38. Between groups risk taking behaviour – Frequency (%) of risky behaviour during alcohol only sessions by ALCOHOL ONLY users vs. AED users

Within subject comparisons indicated that AED users engaged in significantly higher rates of risk taking behaviour during “alcohol only” sessions than during “AED” sessions (see Figure 39). On average, AED users reported 7.1 risk-taking events (SD=4.5) during alcohol only sessions in the past 12 months, compared to 4.3 (SD=4.3) during AED sessions ( $t_{(730)}=21.480$ ,  $p<0.001$ ). The effect size was moderate/strong for this relationship ( $d=0.651$ ).

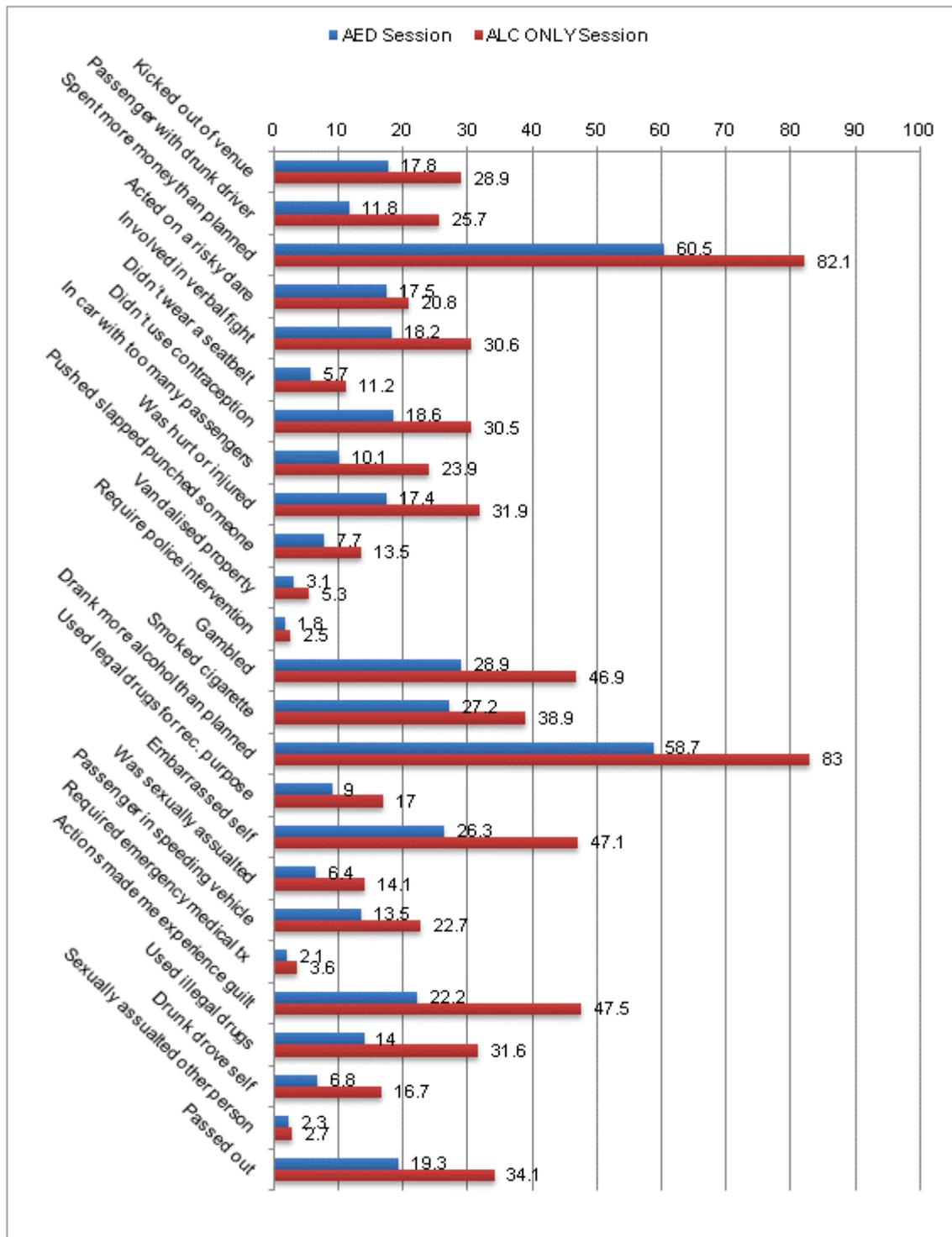


Figure 39. Within group risk taking behaviour– Frequency (%) of risky behaviour during ALCOHOL ONLY sessions vs. AED sessions by AED users

AED users who reported typically mixing greater than 2 standard energy drinks (over the recommended daily limit) reported a significantly higher number of risk taking behaviours. On average, AED users who mixed more than 2 EDs reported 5.8 risk-taking events (SD=4.8) during AED sessions in the past 12 months, compared to 3.2 (SD=3.5) for AED users who mixed less than 2 EDs ( $t_{(729)}=-8.181, p = <0.001$ ). The effect size was moderate/strong for this relationship ( $d=0.606$ ).

Risk taking behaviours increased in a linear direction relative to number of EDs typically consumed in an AED session. Risk taking behaviours here are limited to reports of aggression (physical, verbal or sexual), driving while intoxicated, injuries to self or others, acting on a risky dare, and experience of guilt post intoxication within the past 12 months. Reported rate of risk-taking behaviours were most commonly reported after consumption of between 4-6 AEDs for all behaviours reported (Figure 40).

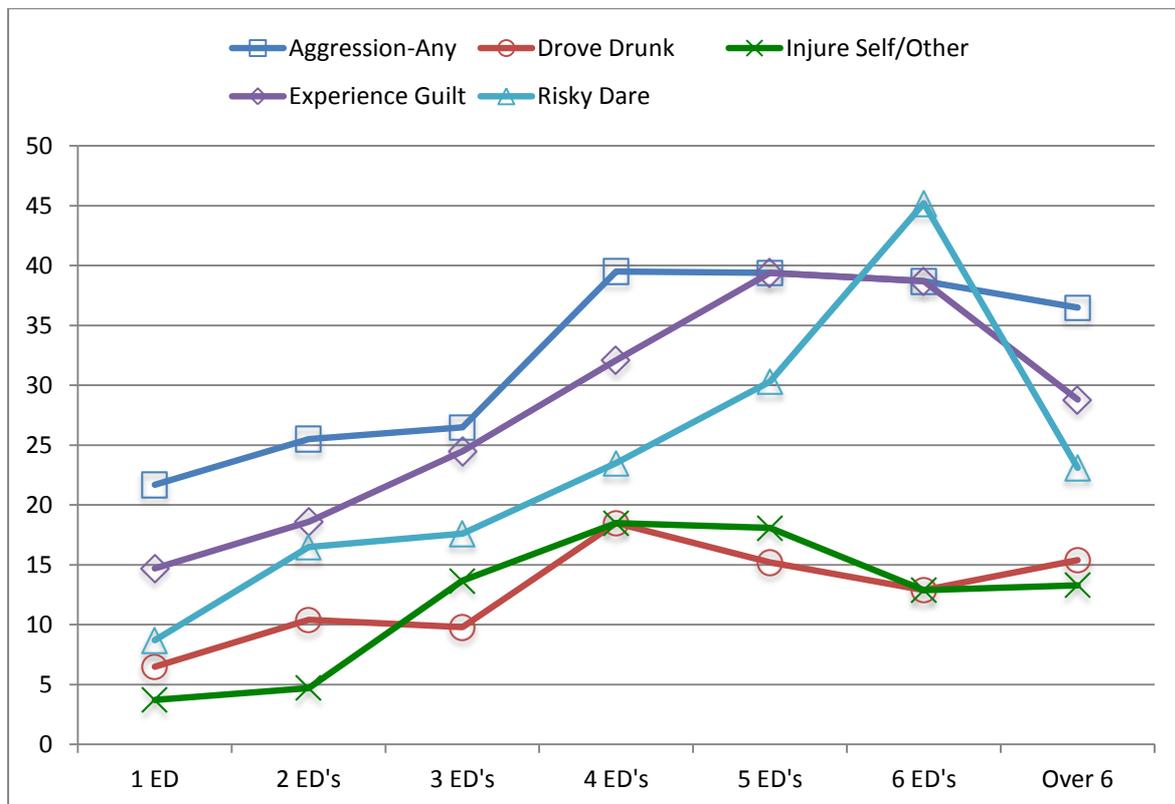


Figure 40. Prevalence of risk behaviours: aggregated data presenting average energy drink consumption during typical AED sessions in past 12 months (%)

## 4.4 Street Survey

### 4.4.1 Methods

#### 4.4.1.1 Measures

The street survey contained the following sections:

- Introduction and consent;
- Demographic data (i.e., age, gender);
- Patterns of alcohol use, ED use and AED use;
- AUDIT-C (178);
- Why/why not use EDs and AEDs (motivations/harms);
- Aggression/violence and risk-taking behaviour; and
- Blood alcohol concentration (BAC) reading<sup>12</sup>

#### 4.4.1.2 Sample

The population of interest in relation to AED use are those using them within the night-time economy (NTE). It is for this reason that the majority of street intercept surveys were performed in a range of nightlife locations in metropolitan and regional areas. Inclusion criteria were (i) aged 16 years or over and (ii) a resident of New South Wales.

#### 4.4.1.3 Setting

The majority of data was collected in the Sydney metropolitan area. The City of Sydney has the most active and diverse night-time economy in New South Wales and, as such, was deemed likely to provide the most representative and informative research outcomes. The following locations were selected due to their prominence to Sydney's NTE and their potential to recruit interviewees of the target age range. Late-night interviews were conducted on Saturday nights (10pm-2am) at sites 1 and 2 and evening interviews were conducted on Friday nights (6pm-10pm) at sites 3 and 4. This design maximised the potential to elicit a representative sample of young people who frequent the night-time economy.

1. Darling Harbour/Cockle Bay Foreshore (10pm-2am Saturday nights): This entertainment and dining precinct attracts a highly diverse patronage. This area is busiest when bar and nightclub patronage increases, traditionally between 10pm-2am. However, this area also captures patrons attending the many restaurants and entertainment options in the area (i.e., IMAX, the Casino, etc.). Saturday night was preferred to Friday night because it attracted a younger demographic that was regarded as central to the study.
2. Kings Cross (10pm-2am Saturday nights): Kings Cross is Sydney's busiest nightlife precinct. The strong pedestrian presence in the area, combined with the high density of late-night trading licensed venues, created an ideal setting for performing street intercept surveys.

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<sup>12</sup> Blood alcohol concentration was estimated from breath using a breathalyser.

3. Town Hall (6pm-10pm Friday nights): As Sydney's most central transport hub, the Town Hall is both a start and end point for people travelling through the city. The area also offers a broad range of entertainment options, including cinemas, gaming arcades, late-night shopping establishments, as well as a number of late-trading bars and nightclubs. Surveys were undertaken around the Town Hall train station, which is also a meeting point for many people on their way to other venues in the area.
4. Circular Quay (6pm-10pm Friday nights): Circular Quay is one of Sydney's most popular tourist destinations. It is also a key transport hub and, again, offers access to a number of different entertainment options, including bars, restaurants, museums, cinemas and the Sydney Opera House. Surveys were performed around Circular Quay Train Station and Ferry Terminal.

### **Regional sites**

Regional data collection took place in Newcastle and Orange. Consensus was reached about targeting Orange and Newcastle based upon the following reasoning:

- Newcastle represents a larger regional hub with a population of approximately 230,000 people and Orange has a population of approximately 35,000.
- Orange contains the largest campus of Charles Sturt University and Newcastle also contains a significant university population.
- Orange and Newcastle experience yearly peak alcohol related violence rates during the intended data collection period, whereas other regional sites peak earlier.
- Data had previously been collected in Wollongong for the Patron Offending and Intoxication in Night-Time Entertainment Districts (POINTED) project and those findings could be drawn on for the current study.

#### **4.4.1.4 Survey Procedure**

Brief structured interviews were conducted at the locations identified above on a weekly basis over a 12-week period. Data were collected between December 2012 and February 2013. Researchers worked in groups of ten in public thoroughfares within the selected areas for four hours on Friday and Saturday nights, starting as early as 6pm and finishing as late as 2am.

Each week, a research team of 10 trained interviewers conducted interviews over a 4-hour period. All staff were required to attend training in the use of equipment such as breathalysers and iPod Touch devices, which were used to record interview data. Extensive safety training was provided prior to commencement of data collection, including how to handle incidents of aggression, situations where participants were highly intoxicated or situations where police or venue operators requested the results of data or breathalysers. Training also involved basic research methods training such as sampling, how to build interviewer/interviewee rapport, how to effectively conduct interviews and how to identify signs of alcohol and other drug intoxication.

Each team was allocated a team leader who was responsible for liaising with the venue staff and police, carrying support equipment and overseeing team operations and safety. All interviewers wore easily identifiable clothing from the University of Western Sydney (UWS).

Research staff approached potential interviewees in major pedestrian thoroughfares, at transport hubs, and outside licensed and other entertainment venues, including cinemas, gaming arcades, restaurants, pubs and nightclubs. Interviewees were selected randomly to ensure a representative sample was achieved. In addition to this, people who had not been approached for an interview but expressed a desire to be interviewed were interviewed to ensure good relations with patrons and avoid difficult situations.

Staff identified as being from UWS. They explained to the potential interviewee that a study was being conducted into AED consumption patterns and behaviour and that involvement was entirely voluntary, that the survey would take around five minutes to complete and was completely anonymous. If participants agreed to be involved, they received a business card sized information/consent card with project details and contact details for the research team and ethics committee. Once they gave verbal consent the interview commenced. An individual record was created for each person approached.

Interviewers were trained in the identification of intoxicated persons and patron interviews were not conducted with people who were heavily intoxicated, and unable to provide consent. Where intoxication was not evident until the interview had begun, the interviewer ended the survey prematurely, thanked the participant for their time and informed them they had answered all the questions. All prematurely ended surveys were recorded as such, and all refusals were recorded to measure response rate.

At the conclusion of the interview, participants were asked to provide a breathalyser test to measure their BAC. If they agreed, the BAC result was then recorded as part of the survey, otherwise the decline was noted. All participants were advised of their BAC. All participants were subsequently informed that the tests did not represent an assessment of their legal ability to drive.

#### **4.4.1.5 Data Analysis**

Data was collected using iPod Touch devices running 'Tap Forms' software, which is automatically transported into Microsoft Excel. All analyses were conducted using IBM SPSS Statistic v.21 (179). Frequency and descriptive statistics were calculated for all categorical variables. Mean, standard deviation (SD) and ranges were calculated for numerical and scale variables. Paired sample t-tests, independent sample t-tests, and chi-square tests were used to test the statistical significance of differences between and within sample groups. As with the web-survey, effect size of differences is represented using Cohen's *d* statistic.

#### 4.4.1.6 Ethics

Ethics for this project was approved by Deakin University HREC and HEAG-H.

Approval numbers:

- HEAG-H-61-2012
- DUHREC 2011-095
- DUHREC 2012-257

#### 4.4.2 Results

##### 4.4.2.1 Description of the Sample

At the conclusion of data collection  $n=1,307$  unique participants had been approached to commence the survey. Table 24 provides a summary of cases removed from analysis as a result of incomplete responses or numerical outliers. Cases were removed if they were missing data for items deemed critical to the research question or the progress logic of the survey. Case-by-case cleaning indicated a response and inclusion rate of 97%, yielding a final sample size of  $n=1,265$ , exceeding the project target.

*Table 24. Summary of cases removed from analysis*

Reason for Removal	<i>n</i>
False starts/declined interviews	17
Demographic data not recorded	18
Other key consumption data not recorded	7

Further missing data is declared for each analyses presented. Cases were considered to contain numerical outliers if they reported any scores greater than plus/minus 5 standard deviations from the mean on any variable. Any such outlier was recoded to be one standard deviation greater than the most extreme score for the given variable. A criterion of 5 standard deviations was chosen as the typical standard of 3 standard deviations was considered too conservative given the inherent variance of the consumption data collected.

Participants were recruited in Circular Quay ( $n=56$ ), Darling Harbour ( $n=229$ ), Kings Cross ( $n=463$ ), Newcastle ( $n=125$ ), Orange ( $n=120$ ) and the Town Hall ( $n=272$ ). Participant ages ranged between 16 and 55 years old, with 92.6% of the sample aged 30 years or below. The mean age of respondents was 22.71 ( $SD = 5.32$ ), the most common reported age was 18 (Figure 41). Over half (58.2%) of the sample were male (Table 25).

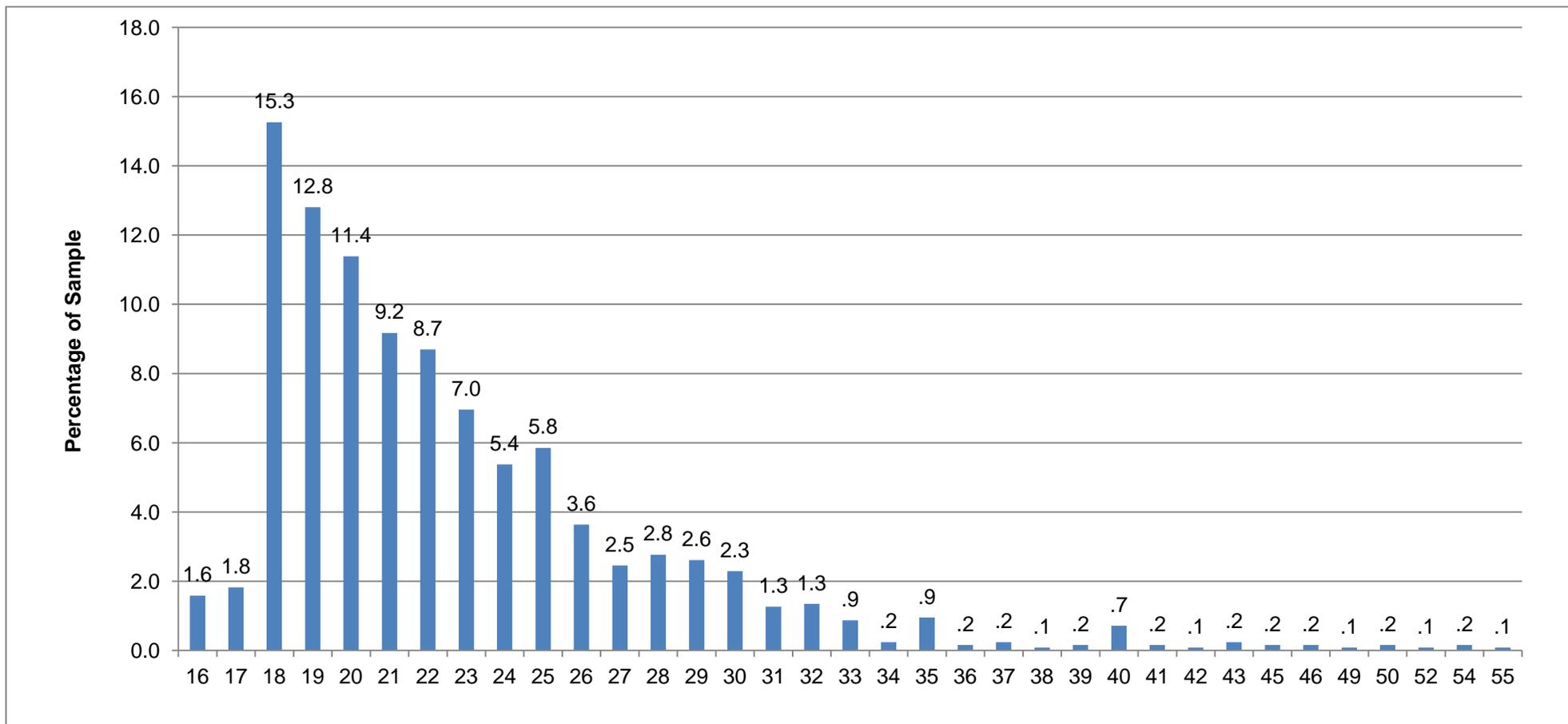


Figure 41. Sample distribution of age (%)

Table 25. Descriptive statistics for demographic variables

Variable	(n)	%
<i>Gender</i>		
Male	736	58.2
Female	529	41.8
<i>Age Bracket</i>		
16-17	43	3.4
18-20	499	39.4
21-25	456	36.0
26-30	174	13.8
31-40	76	6.0
41 and over	17	1.3

#### 4.4.2.2 Alcohol Use

In total, 94.2% of respondents ( $n=1,192$ ) reported having consumed an alcoholic drink in the past 12 months. Overall frequency of alcohol consumption for the whole sample is shown in Figure 42. The most commonly reported frequency for alcohol consumption was “2 to 4 times per month”, reported by 37.9% of the sample.

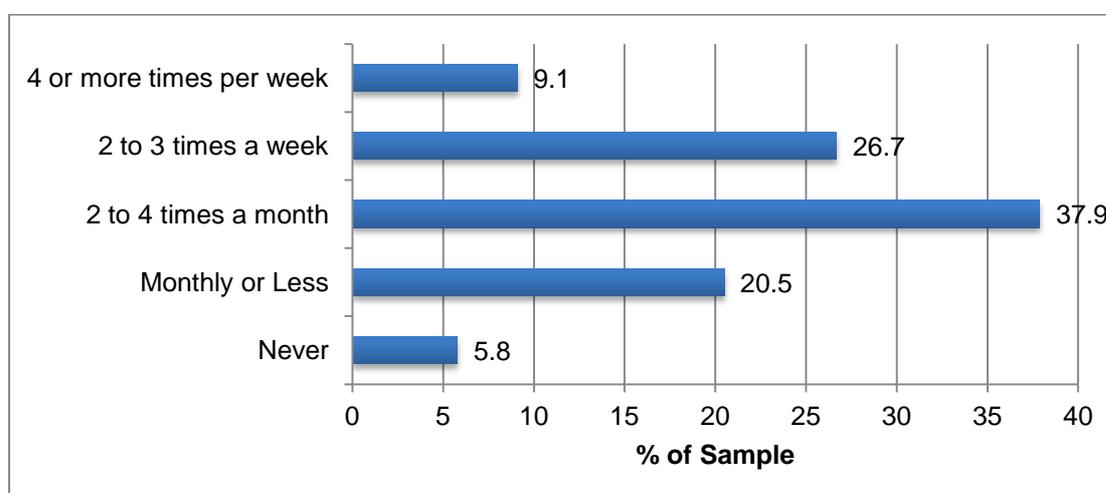


Figure 42. Audit-C frequency of alcohol use in past 12 months

Self-reported number of drinks consumed during a typical drinking session ranged between 0 and 36, with almost two thirds (63.4%) reporting more than 6 standard drinks per typical session. Male participants and those aged 21-25 inclusive consumed the highest amount of alcohol during typical sessions when compared to the sample mean of 8.2 standard drinks ( $SD=5.7$ ; see Table 26).

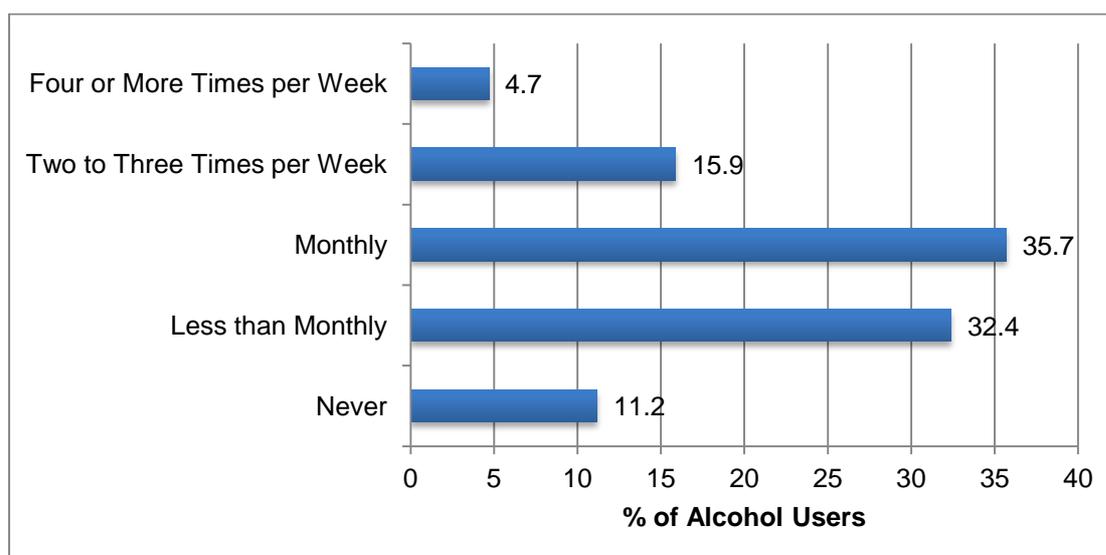
Self-reported number of drinks consumed during the current drinking session (the past 12 hours) ranged between 0 and 31, with a sample mean of 5.1 drinks ( $SD=5.5$ ). Similarly, male participants

and those aged 21-25 inclusive consumed the highest amount of alcohol during the current session (Table 26).

*Table 26. Descriptive statistics for all alcohol users*

Variable	Mean (SD)	Male	Female
Number of drinks on typical session in past 12 months (range: 0-36)	8.2 (5.7)	9.3 (6.3)	6.8 (4.3)
16-17	7.8 (3.4)	8.9 (3.8)	6.4 (2.1)
18-20	8.9 (5.4)	9.8 (5.8)	7.8 (4.6)
21-25	8.4 (6.1)	9.8 (6.8)	6.3 (4.0)
26-30	6.8 (5.7)	7.7 (6.3)	5.3 (4.2)
31-40	6.0 (5.2)	7.1 (6.3)	4.7 (2.9)
40 and over	6.5 (3.8)	6.1 (3.5)	7.4 (4.7)
Number of drinks in consumed in past 12 hours (range: 0-31)	5.1 (5.5)	5.9 (6.2)	3.9 (4.3)
16-17	1.1 (4.1)	1.6 (5.5)	0.3 (0.7)
18-20	5.3 (5.2)	6.2 (5.1)	4.2 (3.9)
21-25	5.5 (5.8)	6.5 (6.2)	4.0 (4.9)
26-30	4.6 (5.6)	5.4 (6.4)	3.2 (3.3)
31-40	4.9 (5.1)	5.3 (6.0)	4.4 (3.7)
40 and over	4.9 (5.9)	5.0 (4.6)	4.8 (8.6)

The self-reported frequency of participants consuming six or more alcoholic drinks in one occasion is shown in Figure 43. The most commonly reported frequency for this level of risky drinking was “monthly”, reported by 35.7% of alcohol consumers.



*Figure 43. Frequency of high risk alcohol use - 6 or more drinks on one occasion*

The BAC of the entire sample ranged from .00 to .30, with a mean of .04 (SD=0.06). One third of this group (33.2%) recorded a BAC at or above the .05 legal driving limit. Figure 44 shows an hourly breakdown of BAC levels for all alcohol users. Mean recorded BAC levels increased substantially between 10-11pm, and were highest between 1am and 2am (mean=0.07; SD=0.07).

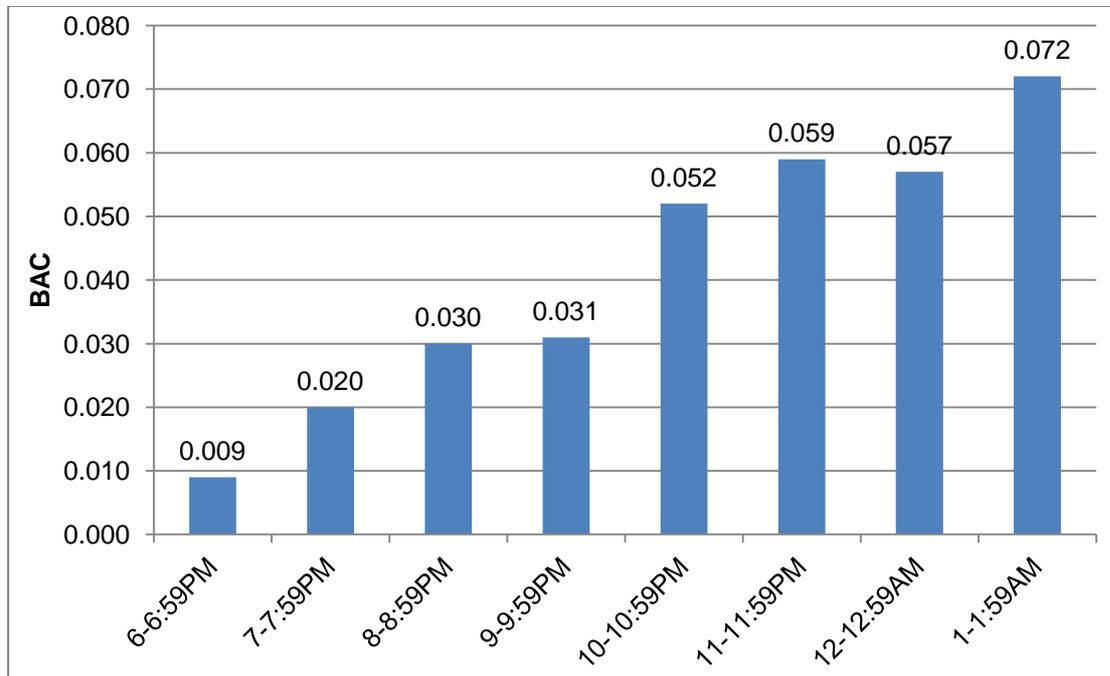


Figure 44. Hourly breakdown of BAC levels for all alcohol users

#### 4.4.2.3 Energy Drink Use

In total, 48.9% of respondents ( $n=619$ ) reported having consumed an energy drink in the past 12 months. Overall frequency of energy drink consumption for ED users is shown in Figure 45. The most commonly reported frequency for ED consumption was “monthly or less”, reported by 36.2% of ED consumers.

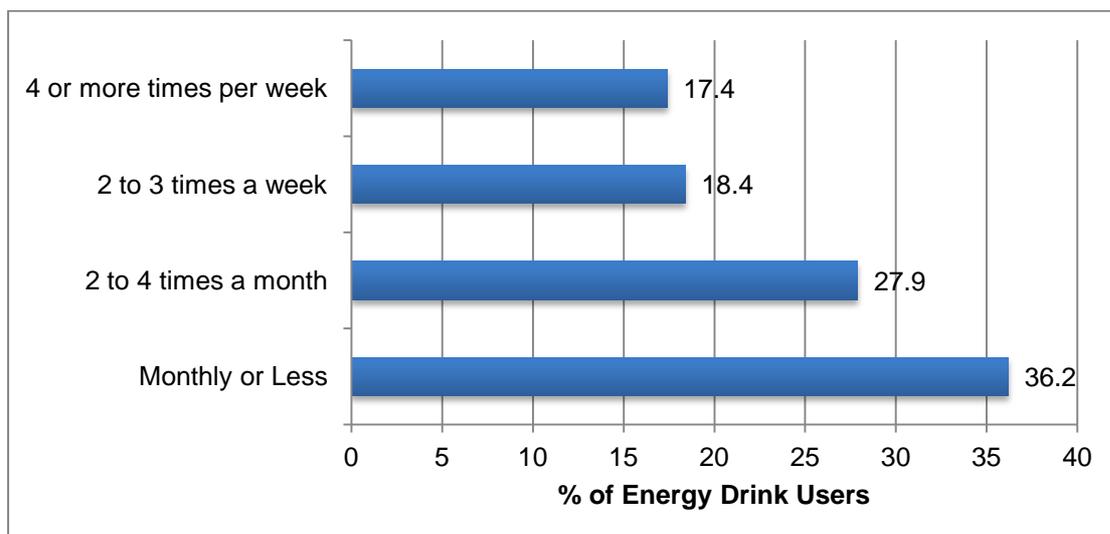


Figure 45. ED Users – Frequency of ED use in past 12 months

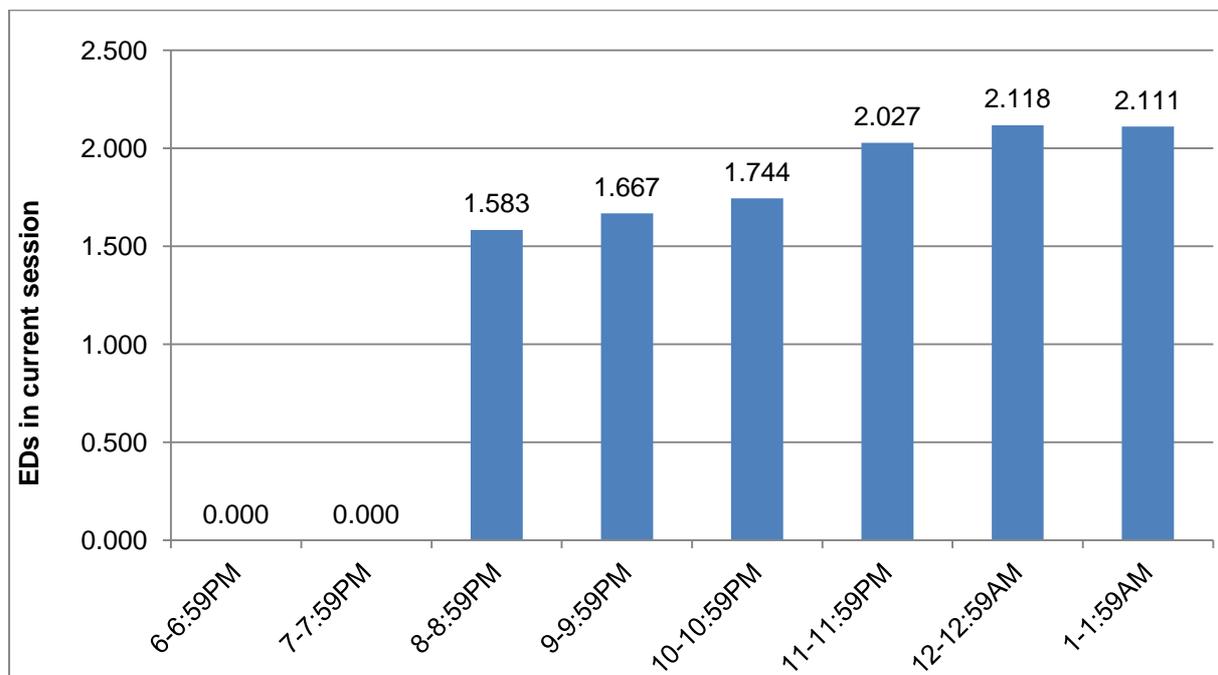
Approximately one third (32.6%) of the current sample reported consuming energy drinks in the current session (last 12 hours). Self-reported number of unmixed energy drinks consumed in the current session ranged between 0 and 6, with the majority (93.3%) reporting 2 or less standard energy drinks, the recommended maximum daily consumption limit in Australia. Female participants and those aged 18 to 20 inclusive consumed the highest amount of unmixed energy drinks in the current session when compared to the sample mean of 1.9 standard energy drinks; however, variation in levels of consumption was low relative to the sample mean (SD=1.4; see Table 27).

*Table 27. Descriptive statistics for all ED users*

Variable	Mean (SD)	Male	Female
Number of ED consumed in past 12 hours (range: 0-6)	1.9 (1.4)	1.9 (1.4)	2.0 (1.3)
16-17	1.4 (0.5)	1.5 (0.6)	1.3 (0.5)
18-20	2.1 (1.4)	2.0 (1.5)	2.2 (1.4)
21-25	2.0 (1.5)	1.9 (1.4)	2.2 (1.7)
26-30	1.6 (1.3)	1.9 (1.5)	1.1 (0.3)
31-40	1.1 (0.9)	-	1.3 (0.6)
40 and over	-	-	-

\*blank cells had insufficient *n* to calculate

Figure 46 demonstrates the average rate of self-reported unmixed EDs consumed by participants over the course of the current session. By 12am, mean self-reported unmixed energy drink consumption had exceeded daily recommended intake, and was highest between 12am-1am, with 2.12 drinks on average.



*Figure 46. Hourly breakdown of ED use for all ED users*

#### 4.4.2.4 Alcohol and Energy Drink Use

In total, 37.5% of respondents ( $n=474$ ) reported having combined alcohol and energy drinks in the past 12 months. Overall frequency of AED consumption among AED users is shown in Figure 47. The most commonly reported frequency of AED consumption was “monthly or less”, reported by 53.4% of the AED users.

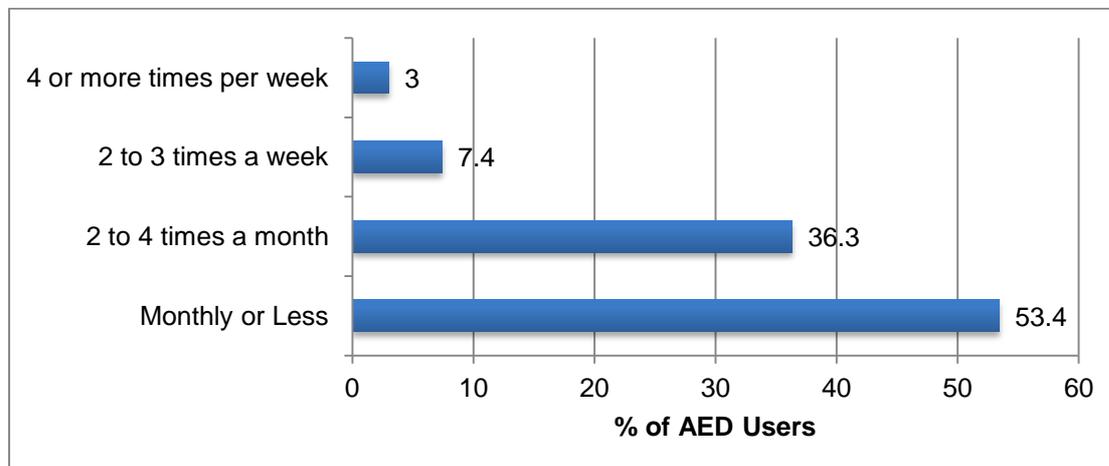


Figure 47. AED Users frequency of AED USE in past 12 months

Over half (55.5%) of AED users reported that they consumed more than 2 standard energy drinks in a typical AED session, exceeding recommended daily intake ( $m=3.55$ ,  $SD=2.84$ ). When asked to report maximum energy drink consumption during an AED session in the past 12 months, 73.1% of AED users consumed more than the recommended daily limit of 2 energy drinks (Table 28).

Male AED users reported higher levels of alcohol use during typical AED sessions when compared to females. On average, male AED users consumed 9.3 ( $SD=6.5$ ) alcoholic drinks during “typical” AED sessions, compared to 6.8 ( $SD=4.3$ ) for females ( $t_{(356)}=4.273$ ,  $p<0.001$ ). The effect size for this relationship was moderate ( $d=0.445$ ). However, the proportion of drinks classified as AEDs during typical sessions was approximately 1 in 3 for both male and female AED users. Age did not appear to have a relationship with quantity of AED use.

Table 28. Descriptive statistics for all AED users

Variable	Mean (SD)	Male	Female
Number of EDs on typical AED session in past 12 months (range: 0-20)	3.6 (2.8)	3.8	3.1
Age 16-17	5.4 (3.7)	6.4	4.3
Age 18-20	3.6 (2.9)	4.4	2.5
Age 21-25	3.3 (2.6)	3.5	2.5
Age 26-30	3.5 (2.6)	3.7	3.7
Age 31-40	3.7 (2.6)	3.6	3.8
Age 40 and over	-	-	-
Maximum number of EDs in AED session in past 12 months (range: 0-20)	5.0 (3.9)	5.5	4.2
Age 16-17	6.5 (4.4)	8.0	4.3
Age 18-20	5.0 (3.7)	5.7	3.9
Age 21-25	5.2 (4.5)	5.6	3.9
Age 26-30	4.0 (3.0)	4.7	2.0
Age 31-40	5.0 (3.4)	5.3	4.6
Age 40 and over	-	-	-
Number of Alcoholic Drinks on typical AED session in past 12 months (range: 0-25)	8.4 (5.9)	9.3	6.8
Age 16-17	10.6 (7.1)	12.7	9.0
Age 18-20	7.8 (5.3)	8.8	5.5
Age 21-25	9.1 (6.9)	9.8	6.2
Age 26-30	9.5 (5.7)	9.9	7.8
Age 31-40	9.8 (6.0)	10.6	8.9
Age 40 and over	-	-	-
Maximum number of Alcoholic Drinks in AED session in past 12 months (range: 0-40)	13.0 (8.8)	14.6	10.0
Age 16-17	13.9 (8.2)	16.9	10.3
Age 18-20	11.1 (7.4)	13.6	8.5
Age 21-25	14.3 (8.7)	15.7	9.3
Age 26-30	13.7 (10.7)	17.0	8.5
Age 31-40	14.7 (9.3)	18.6	10.3
Age 40 and over	-	-	-
Participant rated % of drinks which are combined AEDs in a typical AED session. (range: 0-100)	34.8 (28.5)	34.5	35.3
Age 16-17	51.8 (34.7)	58.6	50.0
Age 18-20	38.8 (29.4)	39.6	36.0
Age 21-25	32.6 (27.2)	31.6	38.6
Age 26-30	29.6 (26.8)	35.3	27.5
Age 31-40	26.0 (25.4)	25.6	26.5
Age 40 and over	-	-	-

\*blank cells had insufficient *n* to calculate

Table 29 shows the breakdown of alcohol, energy drink, and AED consumption amongst all participants in the past 12 months. Alcohol consumption was consistent across all age groups in the past 12 months (including 16-17 year olds), indicating that underage people who are present in night-time entertainment districts are likely to be consuming alcohol at higher than average levels for their age group. AED use was more prevalent amongst male participants than females (31.0% of females had used AED's within the past 12 months compared to 42.1% of males).

AED consumption was highest amongst participants aged 18-20, with almost half of this age group reporting AED use in the past 12 months. Approximately one third of participants aged 16-17 reported having consumed AEDs in the past 12 months, slightly higher than respondents in the web survey, and indicates that 16-17 year olds present in nightlife areas are likely to be higher risk alcohol/other drug users than those who responded to the web-survey. AED consumption dropped substantially for participants aged over 30, though not to the same extent as that reported by web survey respondents.

*Table 29. Prevalence of alcohol, ED and AED consumption between age groups: Past 12 months*

Overall prevalence of consumption per each age Bracket (%)	Alcohol	ED	AED
<i>Age 16-17</i>	86.0%	48.8%	30.2%
<i>Age 18-20</i>	95.2%	56.3%	45.7%
<i>Age 21-25</i>	95.4%	45.0%	36.2%
<i>Age 26-30</i>	91.4%	42.5%	26.4%
<i>Age 31-40</i>	93.4%	43.4%	28.9%
<i>Age 40 and over</i>	88.2%	29.4%	0.0%

In total, 10.1% of respondents ( $n=128$ ) reported having consumed AEDs in the current session and 74% ( $n=887$ ) reported having consumed only alcohol in the current session. The mean reported number of AEDs consumed during the current session was 2.7, and was highest between 1am and 2am (mean=3.6; SD=2.7). By 10pm, the average AED user had exceeded the recommended daily intake of energy drinks. Average total ED consumption was highest between 1am-2am when consumers reported an average of 3.6 energy drinks (Figure 48).

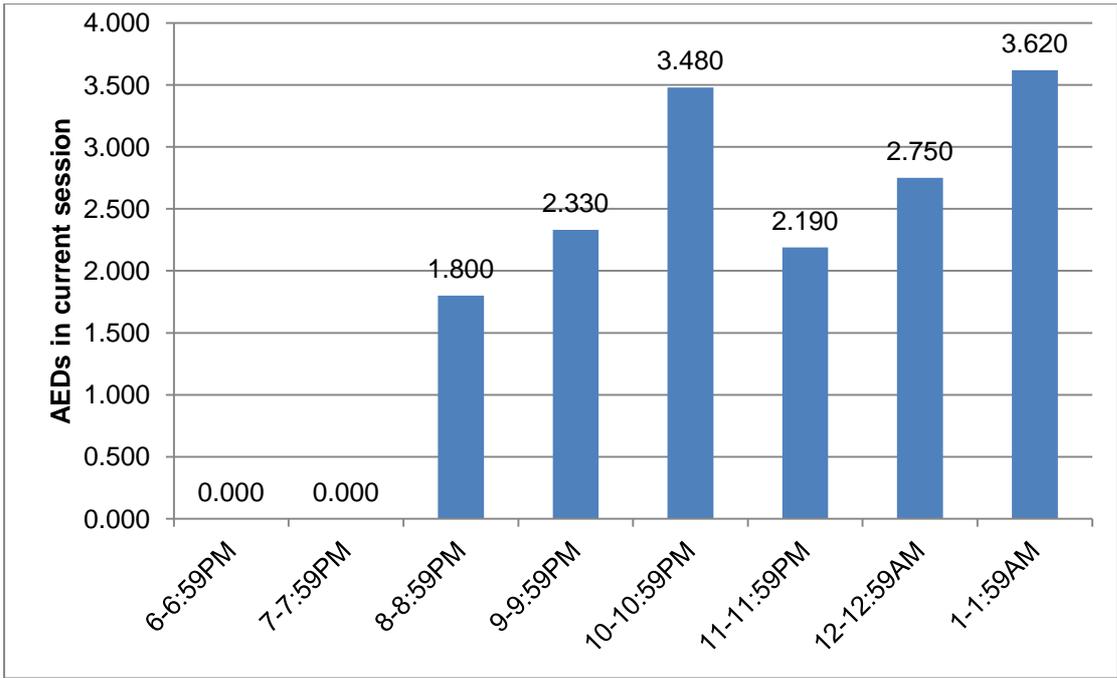


Figure 48. Hourly breakdown of AED consumption in current session for AED users

Table 30 shows a breakdown of key participant demographic and consumption measures according to interview location. Overall, prevalence of alcohol, ED, and AED consumption was consistent across nightlife locations in all cities; however, Newcastle residents consumed significantly more alcohol during the current session, and more energy drinks during the current session (unmixed). Quantity of AED use did not differ according to street interview sites.

Table 30. Key consumption and demographic variables according to street interview location

Variable	Location				
	Sydney (n=1020)	Newcastle (n=125)		Orange (n=120)	
Total Prevalence of Use in the past 12 months (%)					
Alcohol	93.6%	98.4%		95.0%	
Energy Drinks	49.9%	45.6%		44.2%	
AEDs	37.9%	36.8%		34.2%	
	<i>Statistic (SD)</i>	<i>Statistic (SD)</i>	<i>t value (df)</i>	<i>Statistic (SD)</i>	<i>t value (df)</i>
Mean Age of Respondents (yrs)	22.6 (5.1)	23.03 (5.8)	0.872 (1143)	23.3 (6.5)	1.32 (1138)
Gender					
Male (%)	57.9%	60.8%		57.5%	
Alcohol Use (std drinks)					
Current Session	6.6 (5.1)	9.0 (6.6)	3.66 (129.2)**	6.6 (4.9)	0.025 (776)
Energy Drinks (std energy drink)					
Current Session	1.8 (1.3)	2.5 (1.7)	2.22 (195)*	2.1 (1.3)	0.666 (180)
AED Use (AED Sessions)					
Current Session Total					
AEDs	2.9 (2.3)	3.1 (1.9)	0.279 (120)	2.8 (1.5)	0.070 (104)
Typical Session Alcohol	8.3 (6.0)	8.9 (6.1)	0.346 (322)	8.7 (5.5)	0.343 (315)
Typical Session ED	3.5 (2.8)	3.5 (3.1)	0.078 (317)	3.9 (3.2)	0.827 (318)
Max Session Alcohol	13.1 (9.2)	14.1 (7.1)	0.612 (309)	10.8 (6.8)	1.426 (308)
Max Session ED	4.9 (4.0)	5.9 (4.0)	1.399 (299)	5.0 (3.6)	0.219 (300)

Note: The t-tests compare "Newcastle" or "Other Postcode" to "Sydney", which is the baseline variable.

\*sig<0.05

\*\*sig<0.001

#### **4.4.2.5 Between Groups Comparisons: Alcohol Only versus AED Consumers**

AED users recorded a significantly higher BAC of .066 (SD=0.07; range 0-0.30) compared to alcohol only users mean BAC of .051 (SD=0.06) in the current session ( $t_{(885)}=2.753$ ,  $p = <0.01$ ). However, the effect size was small for this relationship ( $d= 0.245$ ).

Between groups analysis using independent sample t-tests demonstrated that participants who were AED users consumed more alcohol in typical sessions than participants who consumed only alcohol. These results were significant with a moderate effect size for typical alcohol sessions ( $M_{ALCONLY}=7.42$ ,  $SD=5.50$ ,  $M_{AEDUSER}=9.54$ ,  $SD=5.62$ ;  $t_{(1191)}= 6.44$ ,  $p = <0.001$ ;  $d=0.381$ ), and indicate that AED users consumed an average of 2 more standard drinks of alcohol in typical sessions compared to alcohol only users.

A further between groups analysis using independent sample t-tests demonstrated that participants who consumed AEDs in the current session consumed more alcohol in that session than participants who consumed only alcohol. These results were significant with a small effect size for standard drinks in the past 12 hours ( $M_{ALCONLY}=4.76$ ,  $SD=5.46$ ,  $M_{AEDUSER}=5.65$ ,  $SD=5.60$ ;  $t_{(1191)}= 2.694$ ,  $p=<0.01$ ;  $d=0.161$ ) and indicate that AED users had consumed an average of 1 more standard drink of alcohol in during the current session compared to alcohol only users.

AUDIT-C scores and risk classifications were calculated for all participants who were alcohol consumers. 2x2 chi-square comparisons indicate a significantly greater proportion of AED users were classified as high risk alcohol users, compared to respondents who consumed alcohol alone ( $\chi^2=37.497$ ,  $p=<0.001$ ).

#### **4.4.2.6 Within Groups Comparisons: AED Consumers**

Within subject comparison analyses ( $n=358$ ) indicated that AED users consumed significantly more alcohol during typical "alcohol only" sessions than during typical "AED" sessions. On average, AED users consumed 9.7 (SD=5.8) drinks during alcohol only sessions, compared to 8.4 (SD=5.9) during typical AED sessions ( $t_{(357)}=4.067$ ,  $p = <0.001$ ). However, the effect size was small for this relationship ( $d= 0.212$ ). This trend was consistent for both males and females who each reported consuming significantly more alcohol during alcohol only sessions compared to AED sessions (t- males  $(_{234})=2.540$ ,  $p <0.05$ ; t-females  $(_{122})=3.953$ ,  $p <0.001$ ). However, this difference was moderate for females ( $d=0.367$ ) and small for males ( $d=0.16$ ).

#### 4.4.2.7 Motivations for AED Use

The most frequently reported motivations for combined AED use included liking the taste, to party for longer, a desire for more energy and to feel a 'buzz' (Figure 49). Motivations relating to price, product availability, mimicking the effect of illicit stimulants, modifying intoxication level, regulating mood and peer pressure were relatively infrequent.

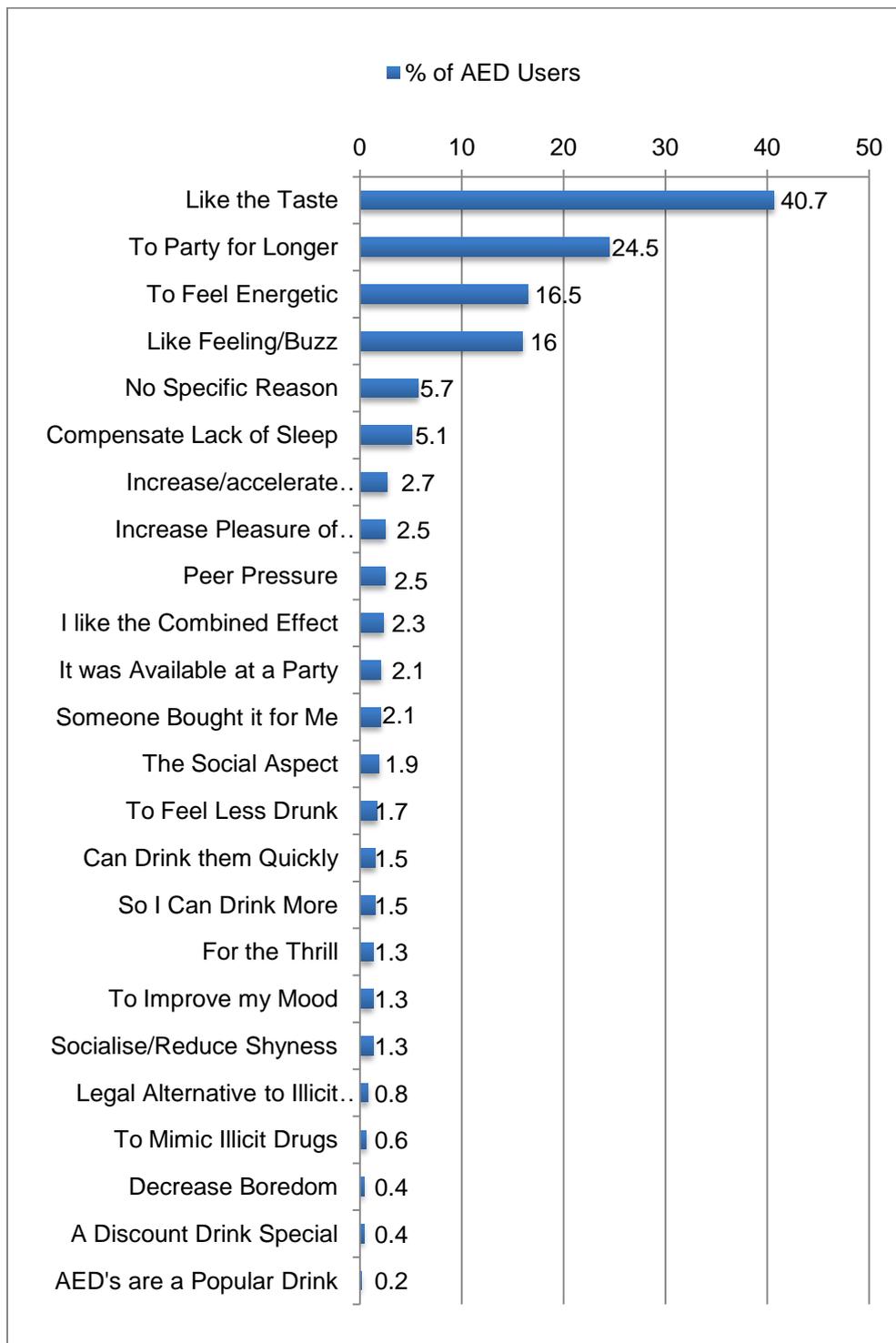


Figure 49. Motivations for AED use

#### 4.4.2.8 Experience of Side Effects: Comparison of Alcohol, Energy Drink and AED users

Consistent with the web-survey, alcohol only users reported hangover, headache, nausea, fatigue and decreased coordination as the most common side effects of alcohol use (Figure 50). Energy drink users reported heart racing and palpitations, energy fluctuations, insomnia, headache and anxiety (Figure 51). Overall, the rate of side effects experienced by ED users was lower than that of alcohol and AED users. However, symptoms of heart racing and energy fluctuations were much higher than that of alcohol users (14.1% and 10.5% compared to 3.2% and 4.1%).

AED users reported hangovers, heart racing and palpitations, headaches, energy fluctuations, nausea, insomnia and increased intoxication as the most common side effects of AED use (Figure 52). Overall, AED users reported a lower rate of side effects experienced compared to using alcohol alone, however rate of heart racing/palpitations was more than double that of alcohol alone (8.7% compared to 3.2%).

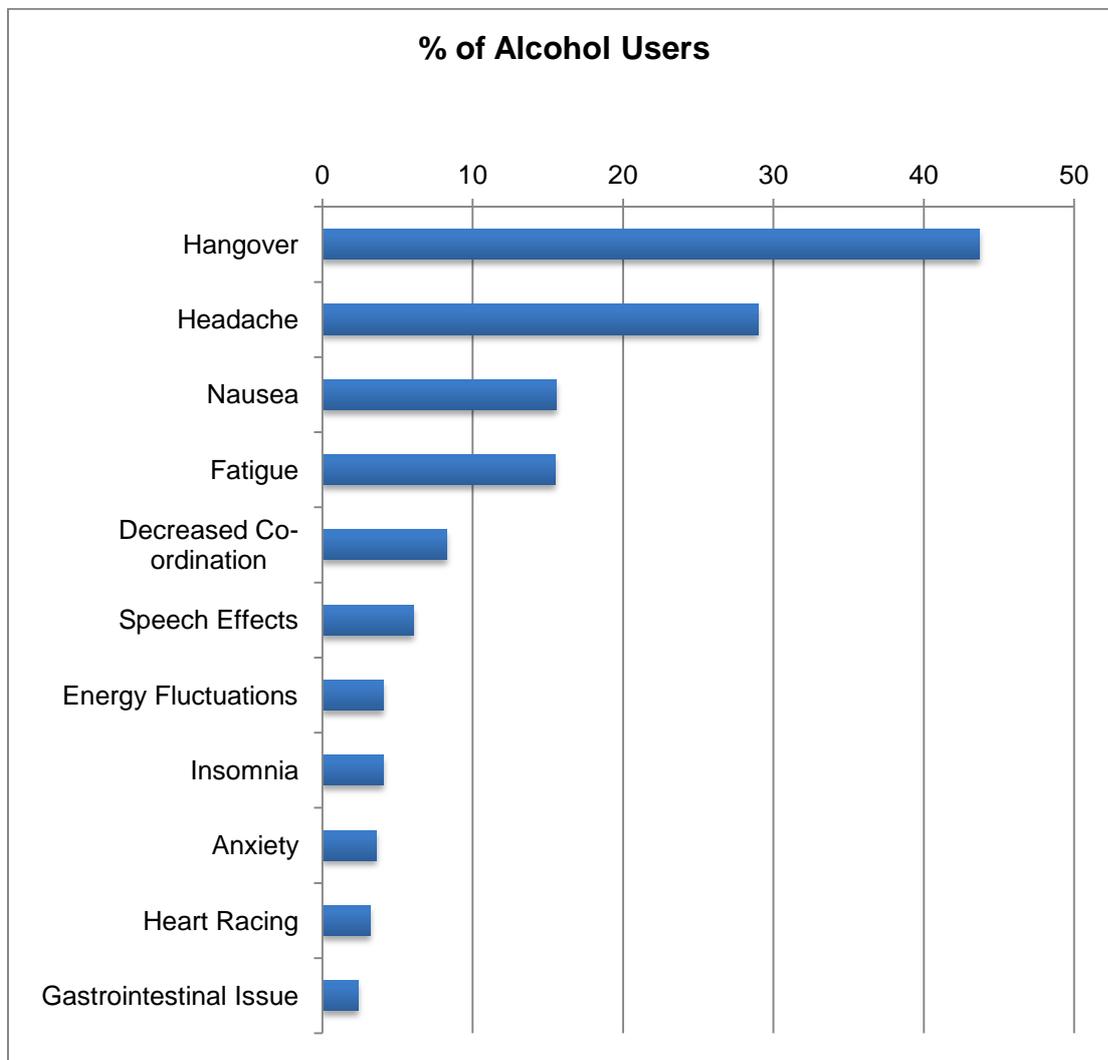


Figure 50. Frequency (%) of side effects experienced by ALCOHOL ONLY users

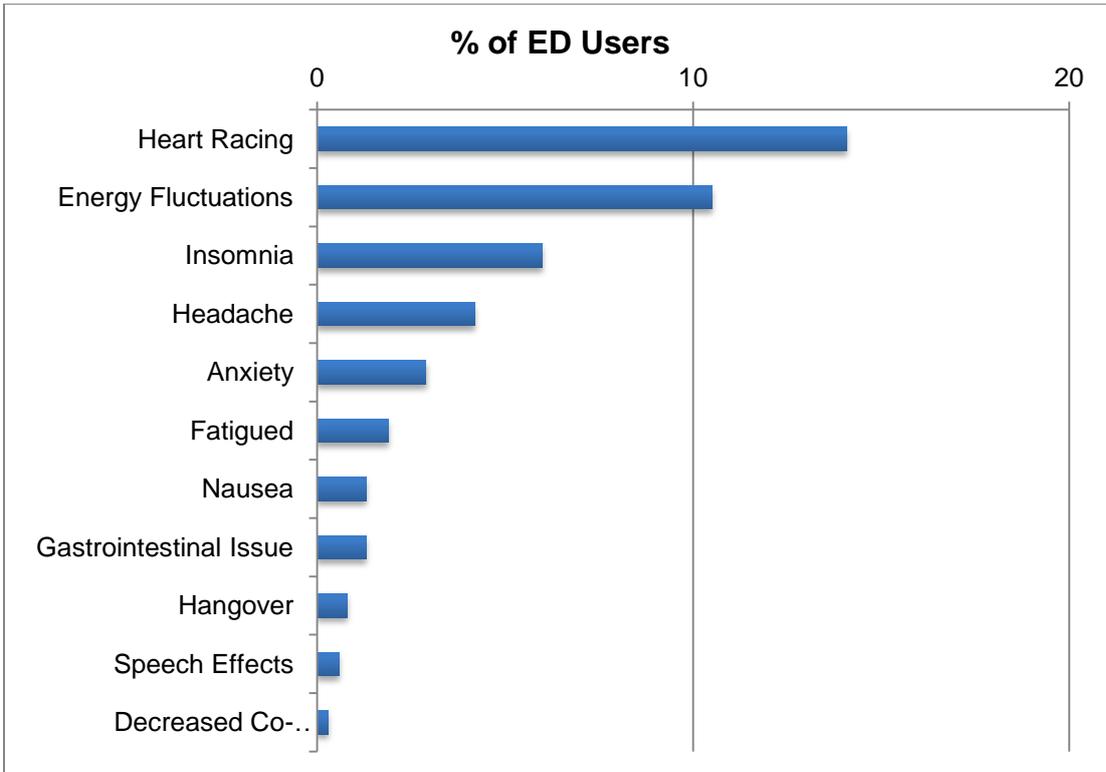


Figure 51. Frequency (%) of side effects experienced by ED users

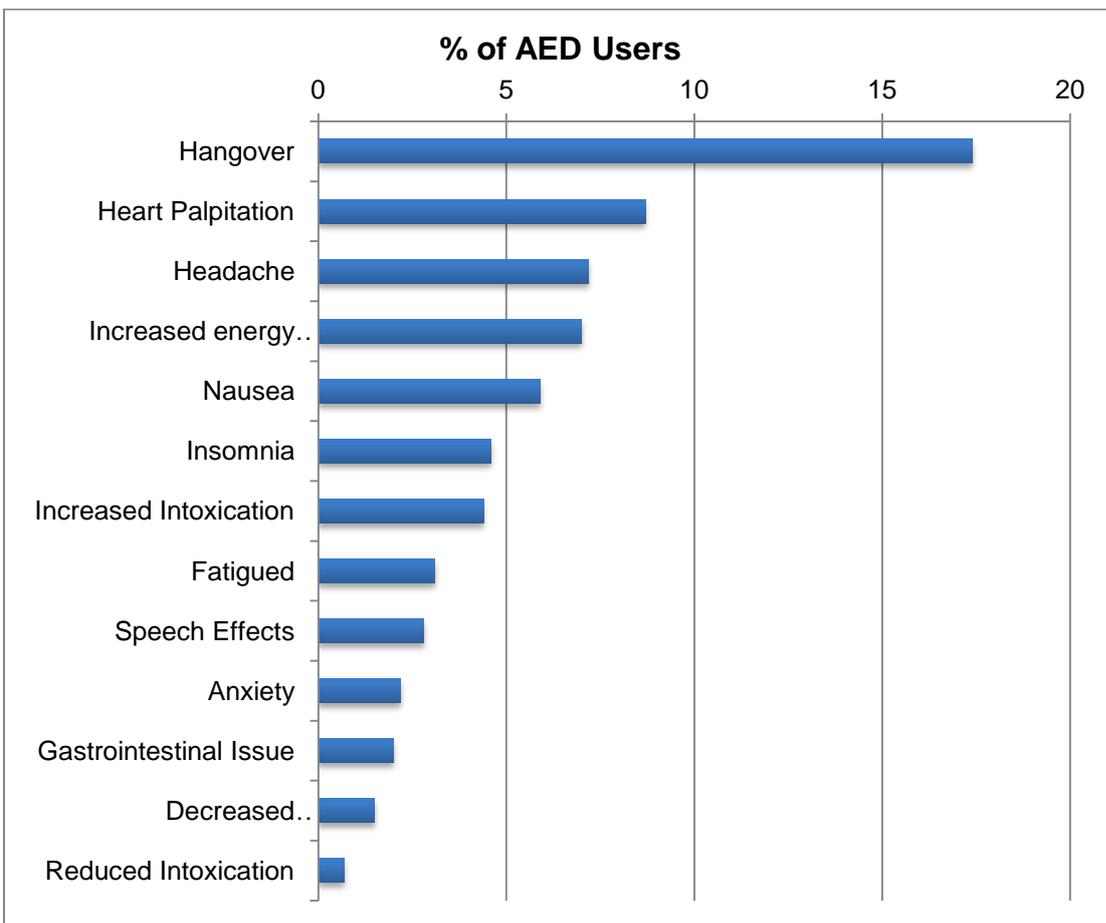


Figure 52. Frequency (%) of side effects experienced during AED use by AED users

#### 4.4.2.9 Reasons for Avoiding Consumption of AEDs

Disliking the taste and physical health concerns were the most commonly reported reasons for participants avoiding AED consumption, in addition to price, concerns about weight/sugar content, sleep/restlessness issues and agitation (Figure 53). Reasons such as experiencing aggression, getting too intoxicated, not getting intoxicated enough and finding alternate stimulants were the least commonly reported.

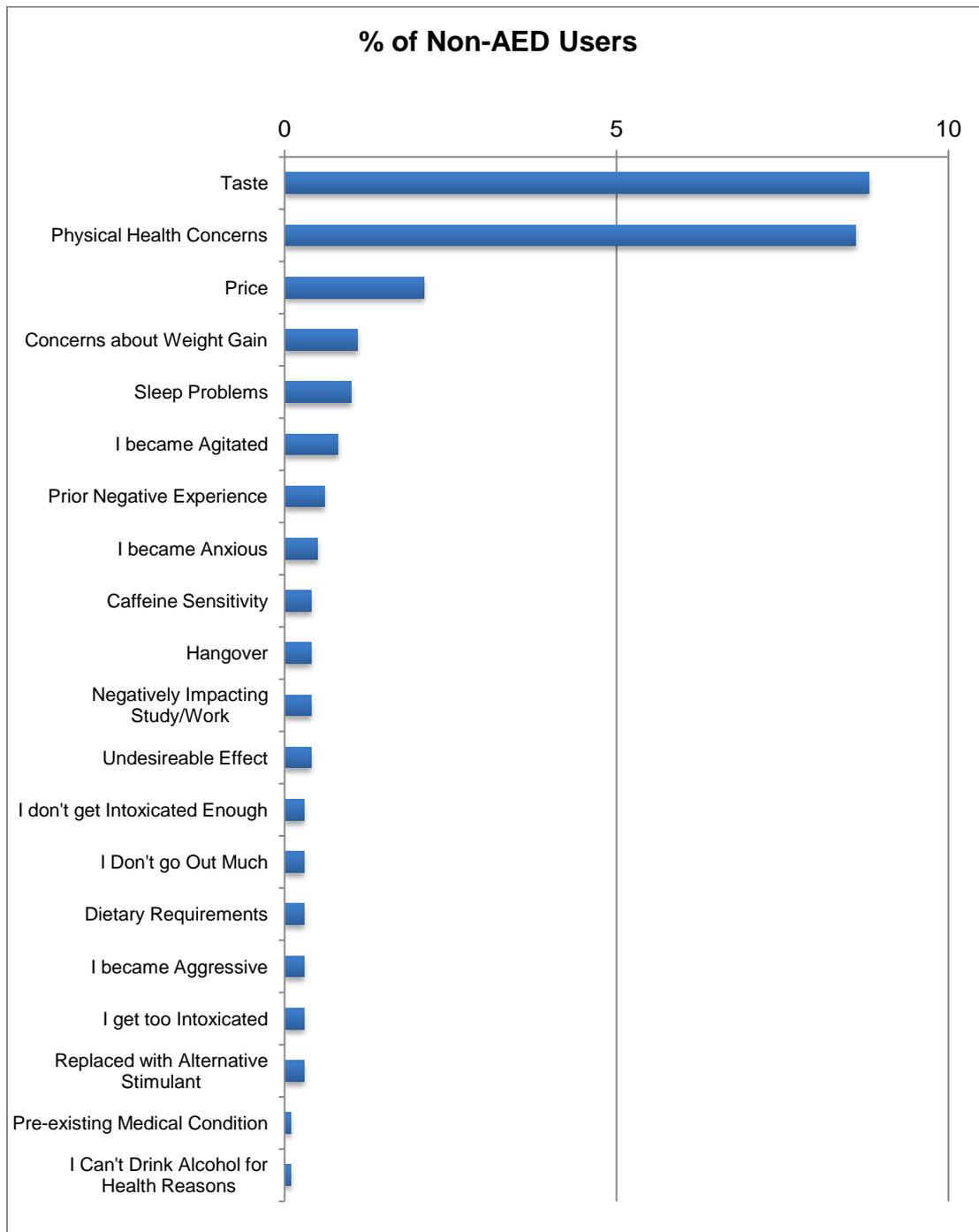


Figure 53. Non-AED Users: Self-reported reasons for not consuming AEDs within past 12 months

#### 4.4.2.10 Involvement in Risk Taking Behaviours and Aggression

AED users were more likely to report having been involved in any type of aggressive incident in the preceding twelve months (33.43%) than alcohol only users (17.06%;  $\chi^2=20.68$ ,  $p<0.001$ ). This result extended to verbal ( $\chi^2=8.67$ ,  $p=0.003$ ), physical ( $\chi^2=10.88$ ,  $p=0.001$ ), and sexually aggressive incidents ( $\chi^2=6.28$ ,  $p=0.01$ ) (Figure 54).

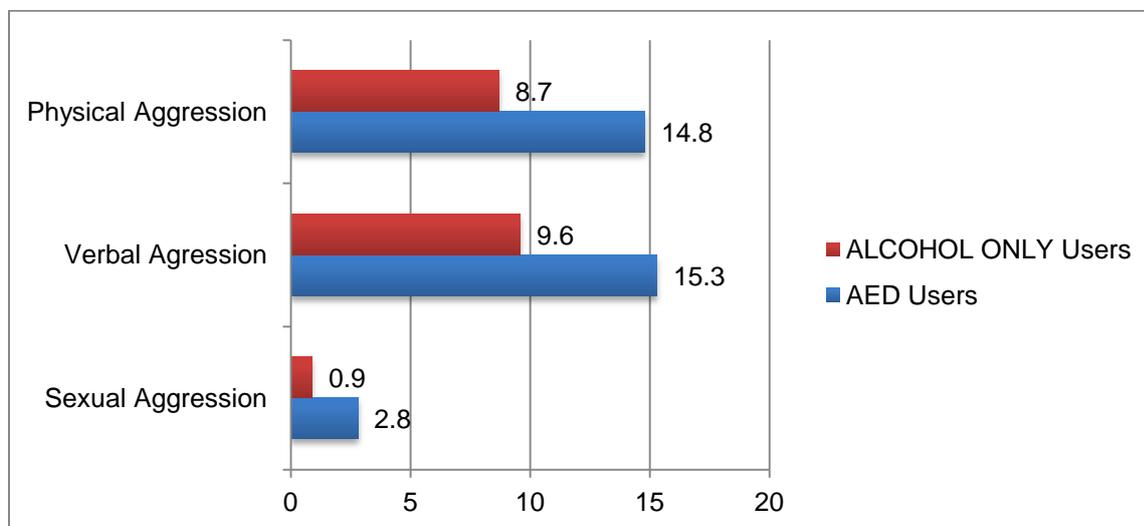


Figure 54. Between groups analysis: Involvement in physical, verbal or sexual aggression in the past 12 months – ALCOHOL ONLY users vs. AED users (%)

However, independent sample t-tests comparing “alcohol only” users and “AED” users demonstrated that amongst those participants who did experience aggression, there was no significant difference in the overall number of aggressive incidents experienced ( $M_{ALCONLY}=4.05$ ,  $SD=5.39$ ,  $M_{AEDUSER}=4.09$ ,  $SD=4.88$ );  $t_{(212)}=.065$ ,  $p = 0.949$ ).

AED users were also more likely to report having driven over the legal BAC limit within the last twelve months (15.62%) than alcohol only users (10.65%;  $\chi^2=4.34$ ,  $p<0.05$ ). Of those participants who reported driving over the legal BAC limit within the last twelve months ( $n=135$ ), 13.3% reported consuming AEDs at the time. However, it is not clear using this research design the role that AED use played in this decision.

Compared to alcohol only users, AED users engaged in aggression more frequently with close friends and acquaintances. However, alcohol only users reported a higher frequency of aggression involving strangers, partners, dealers and “other” individuals.

## 4.5 Comparison with Existing Data – The POINTED Project

### 4.5.1 Introduction to POINTED

The Patron Offending and Intoxication in Night Time Entertainment Districts (POINTED: <http://www.deakin.edu.au/pointed>) study was funded by the National Drug Law Enforcement Research Fund. POINTED was a multi-city nightlife study that aimed to address the significant gaps in evidence in relation to levels of risky drinking among young Australians and harms experienced by young people in and around licensed venues. The POINTED project utilised a research design which enabled researchers to capture data from consumers during an episode of alcohol and other drug use. This approach limited the potential for recall bias, and allowed for first-hand observation of behaviour occurring in and around licensed venues. Short patron interviews ( $n=6,800$ ) were conducted with patrons in 5 cities in New South Wales (Sydney and Wollongong), Victoria (Melbourne and Geelong) and Western Australia (Perth) between December 2011 and June 2012.

POINTED investigated a wide range of substance use behaviours and harms related to night-time environments, including AED consumption. Street intercept interviews contained questions about ED/AED use in the current session, in addition to patron motivations for consumption, side effects experienced, and involvement in aggression/risk taking behaviour. Specific details on the POINTED study design are available in a peer reviewed research protocol (182).

POINTED data presented here has been reanalysed for the purpose of this report, and contains street interview data from NSW sites only (Sydney and Wollongong).

#### 4.5.1.1 Sydney

Interviews with patrons were conducted in Sydney on 10 separate occasions between December 2011 and March 2012. They mostly took place between 10pm and 2am, with one late-night session of interviews running from 1am to 5am. Interviews were held on Friday and Saturday nights in busy entertainment precincts across four CBD and inner-city sites:

- Darling Harbour/Cockle Bay Foreshore
- George Street/Town Hall
- Kings Cross
- Oxford Street, Darlinghurst

Field workers interviewed patrons entering and leaving venues and using popular pedestrian thoroughfares.

#### 4.5.1.2 Wollongong

Patron interviews were conducted in the Wollongong CBD on ten separate occasions between December 2012 and April 2012. Data was collected outside venues on Corrimal, Crown and Keira streets. The Crown Street Mall is the main thoroughfare between venues in Wollongong. Interviews were conducted between 10pm and 2am mostly with patrons walking between venues or waiting in lines, although several venues allowed researchers to conduct interviews on premises.

## 4.5.2 Results

### 4.5.2.1 Sample Characteristics

Of the 2,571 individuals approached in NSW to participate in the study, 2,332 agreed to be interviewed; a response rate of 90.7%. The most commonly reported age was 19 years (10.5% of respondents). Majority (87.9%) of the sample were aged 30 or below (Table 31).

Table 31. POINTED participant sex and age by city/interview site

	TOTAL	Sydney N=1,565	Wollongong N=728
<b>Male, n (%)*</b>	1391 (60.2%)	942 (59.4)	449 (62.0)
<b>Mean age (range)* (years)</b>	24.1 (18-73)	23.8 (18-73)	25.0 (18-65)

\* missing age data for 6 respondents

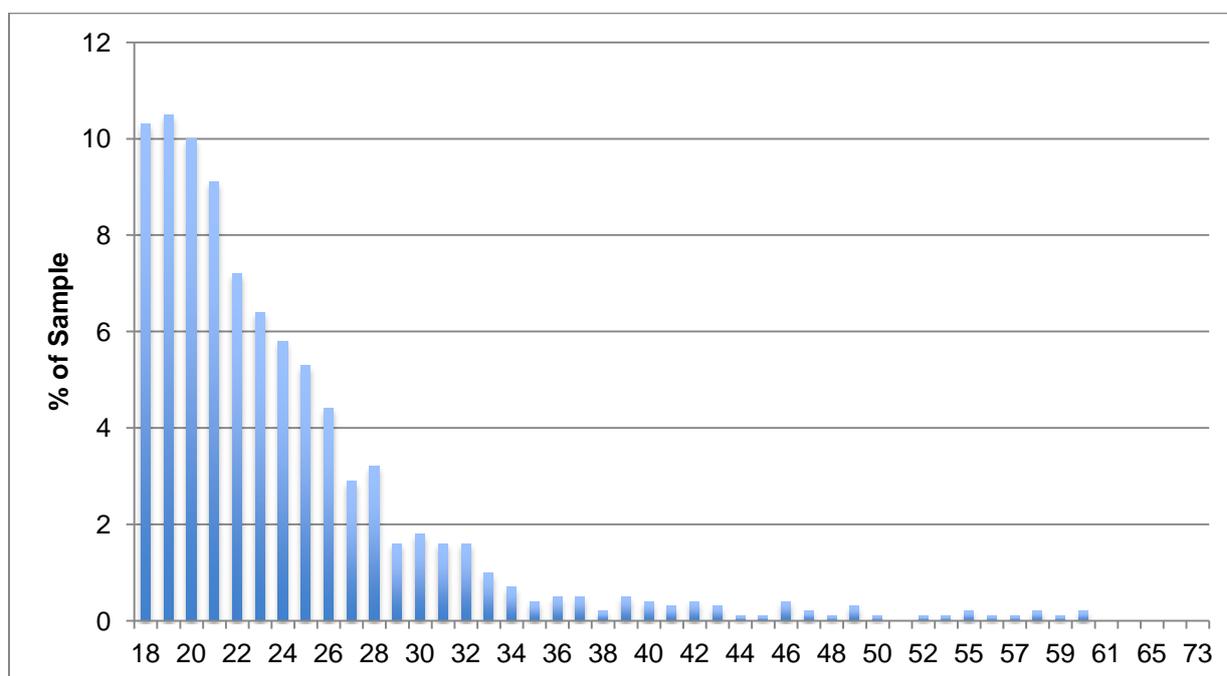


Figure 55. Age distribution of NSW POINTED interviewees

#### 4.5.2.2 Energy Drink Consumption

Nearly a quarter of participants (20.0%) said they had consumed energy drinks in the current session, with 16.0% reporting that they combined energy drinks with alcohol. Male and female participants were similar in their consumption of energy drinks ( $\chi^2=0.10$ ,  $p=0.482$ ) and of alcohol and energy drinks ( $\chi^2=0.28$ ,  $p=0.473$ ). On average, males consumed slightly more energy drinks than female participants, however the difference was not statistically significant. ( $M_{\text{males}}=2.18$ ,  $SD=1.74$ ,  $M_{\text{female}}=1.99$ ,  $SD=1.66$ ;  $t_{(456)}=-1.132$ ,  $p=0.258$ ; see Table 32). There was a negative correlation between age and number of energy drinks consumed ( $r=-0.063$ ); that is, younger participants generally consumed more energy drinks, however the difference was not significant ( $p=0.180$ ), and consumption did not decrease linearly as age increased.

Table 32. Energy drink consumption by age and gender

Variable	Mean (SD)	Male	Female
Number of ED consumed in current session(range: 0-12)	1.8 (1.8)	2.2 (1.7)	2.0 (1.7)
18-19	2.2 (2.0)	2.5 (2.2)	1.9 (1.4)
20-24	2.1 (1.5)	2.2 (1.5)	1.9 (1.4)
25-29	1.9 (1.7)	1.9 (1.6)	2.0 (2.0)
30-39	2.3 (2.0)	1.5 (0.6)	3.3 (2.7)
40 and over	1.2 (0.4)	-	-

\*blank cells had insufficient  $n$  to calculate

As with the other two survey components, participants who consumed alcohol with energy drinks self-reported consuming significantly more alcohol than those who consumed only alcohol ( $M_{\text{ALCalone}}=7.82$ ,  $SD=5.82$ ,  $M_{\text{AED}}=10.38$ ,  $SD=6.67$ ;  $t_{(332)}=-3.114$ ,  $p=0.002$ ;  $d=-0.342$ ). The effect size for this relationship was moderate/low. In addition, participants who consumed energy drinks were significantly more likely to report pre-drinking ( $\chi^2=58.659$ ,  $p<0.001$ ) and significantly more likely to report illicit drug use ( $\chi^2=33.686$ ,  $p<0.001$ ) compared with those who had not consumed energy drinks.

Participants who consumed AEDs generally recorded a higher BAC reading than participants who reported alcohol alone ( $M_{\text{ALCalone}}=0.057$ ,  $SD=0.058$ ,  $M_{\text{AED}}=0.075$ ,  $SD=0.054$ ;  $t_{(333)}=-2.596$ ,  $p=0.01$ ;  $d=0.285$ ). The effect size for this relationship was small/moderate. Further, there was a positive correlation between number of energy drinks consumed and BAC reading ( $r=0.081$ ,  $p=<0.05$ ); that is, participants who reported consuming more energy drinks generally recorded higher BAC readings. People who had consumed energy drinks also self-reported higher mean levels of intoxication ( $M_{\text{NOeds}}=3.49$ ,  $SD=2.34$ ,  $M_{\text{EDs}}=4.46$ ,  $SD=2.32$ ;  $t_{(1528)}=-6.802$ ,  $p=<0.001$ ;  $d=-0.348$ ). The effect size for this relationship was moderate.

Figure 56 reports the mean number of energy drinks consumed by interviewees overall and across both interview sites. The sites show a consistent increase in consumption, with the highest number of energy drinks (approximately 3 energy drinks) being consumed between 1am-2am in Wollongong and

Sydney, one above the recommended daily intake. Figure 56 shows that mean consumption increases to more than two EDs between 11 pm and midnight. Note that data collection finished at 1am in Wollongong due to licensed venue closing times.

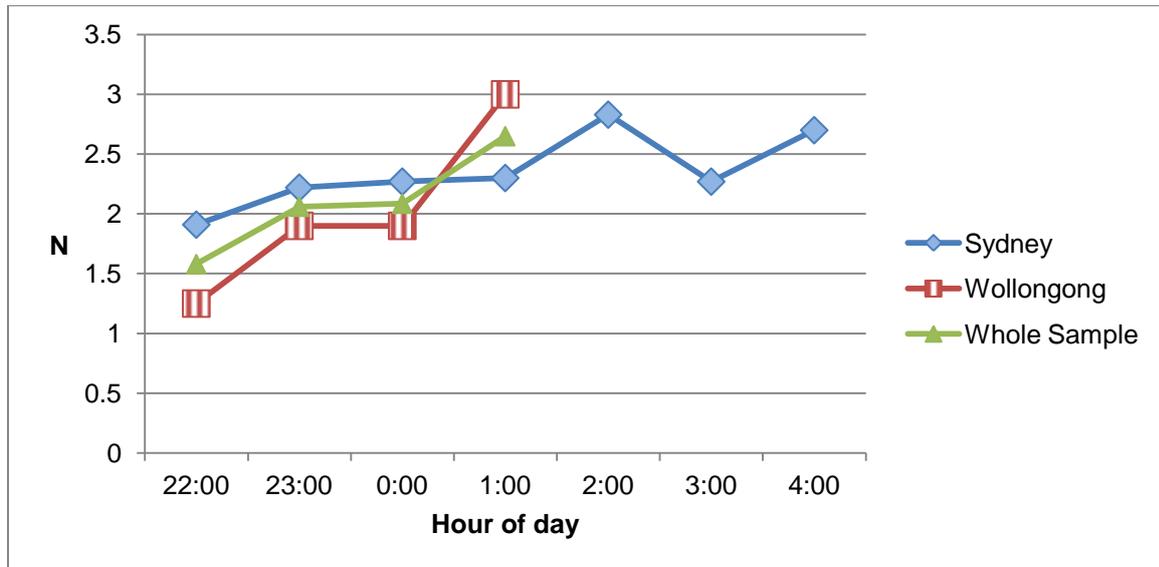


Figure 56. Mean energy drinks consumed by hour of day

Figure 57 shows the percentage of interviewees who reported consuming alcohol mixed with energy drinks throughout the night. As with energy drink consumption alone, the trends are similar for both sites. At 1am both sites had between 20-25 percent of people interviewed reporting having consumed AEDs.

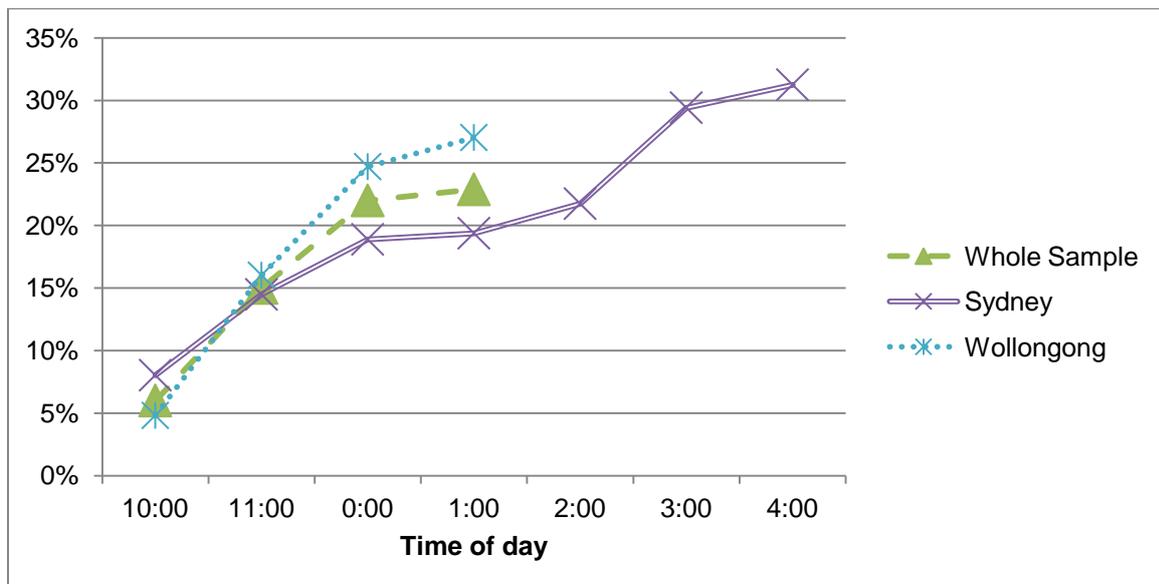


Figure 57. Percentage of interviewees consuming AEDs by hour of day

Participants were asked to report their main motivation for combining energy drinks and alcohol (Figure 58). As with the other survey components, those who answered this question ( $n=262$ ) most commonly reported liking the taste of the combined drinks (32.4%), and that combining these drinks provided them with energy to stay awake/party longer (22.9%). Smaller proportions reported that they enjoyed the feeling/buzz (5.7%), or that the combination increased/boosted alcohol intoxication (7.3%).

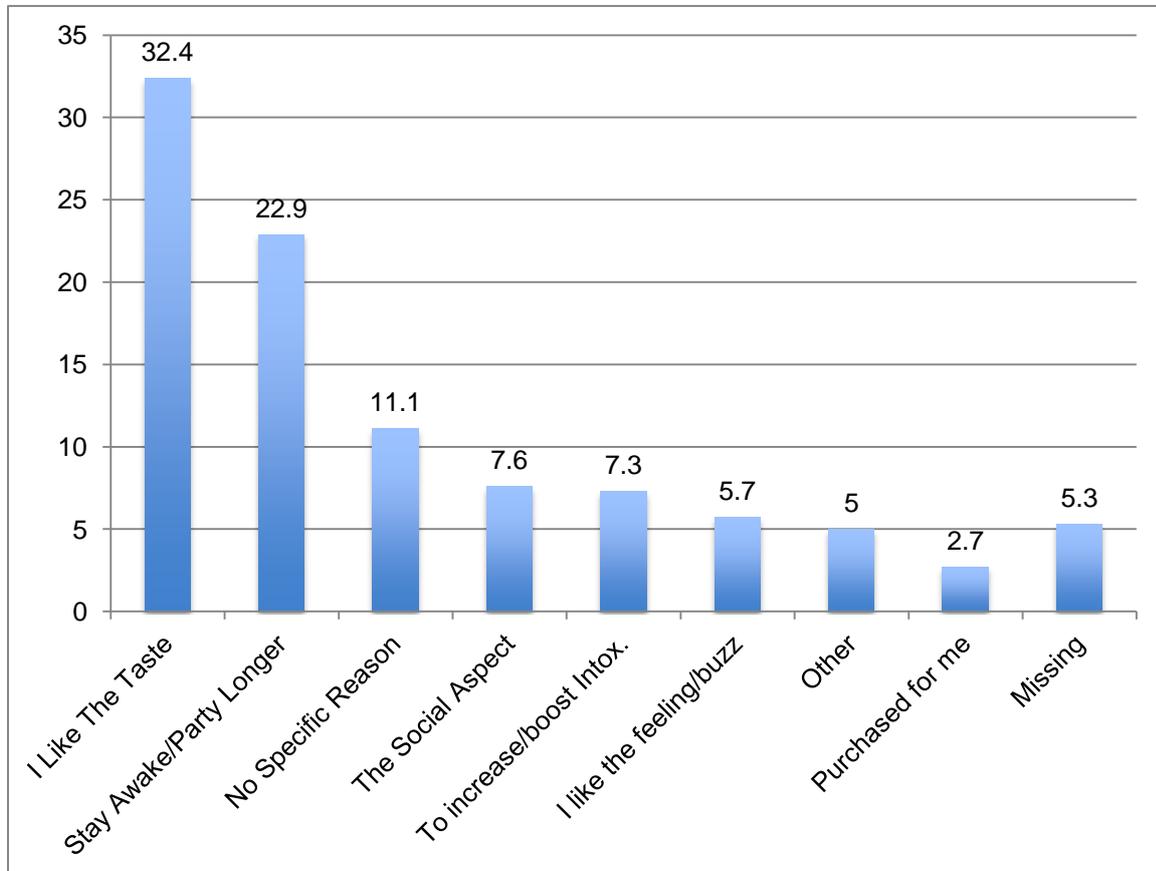


Figure 58. Main reported motivations for mixing energy drinks and alcohol (N=262)

#### 4.5.2.3 Energy drink use and experience of aggression/harm

As with the other survey components, people who reported consuming energy drinks were also more likely to experience any form of aggression in the past three months than those who had not ( $\chi^2=12.922$ ,  $p=0.000$ ). Table 33 reports the number of people who experienced different types of aggression, and their energy drink use. As shown in the table, people who reported energy drink use on the night of interview were significantly more likely to report experiencing verbal or physical aggression over the past three months. The difference was not significant for sexual aggression, potentially because of the small numbers involved. Table 33 also shows that people who reported consuming energy drinks on the night of interview were more likely to report having experienced an alcohol-related accident in the previous three months.

Table 33. Energy drink use and experience of harm in past three months

	Consumed energy drinks tonight (%)		Chi-square	p
	Yes n=402	No n=1,540		
Any aggression around licensed venues last three months?	113	277	12.922	0.000
—physical aggression	77	182	9.898	0.002
—verbal aggression	63	163	4.879	0.027
—sexual aggression	10	32	0.074	0.786
Any accident/injury past three months	87	211	9.356	0.002

#### 4.5.2.4 Energy drink use and offending behaviour

People who had consumed energy drinks on the night of interview were also more likely to report having been refused entry to a venue in the past three months than those who had not ( $\chi^2=8.362$ ,  $p=0.004$ ). Of those who had had been refused entry in the three months prior to interview, 27.4% had consumed energy drinks, compared with 20.3% of those who had not.

However, amongst NSW respondents in the POINTED study there was no significant relationship between energy drink consumption and drink driving behaviour ( $\chi^2=0.321$ ,  $p=0.571$ ) or having committed property crime ( $\chi^2=1.652$ ,  $p=0.199$ ) while intoxicated in the past three months. Overall, 22.7% of those who had consumed energy drinks reported drink-driving compared with 20.9% of those who had not.

## 4.6 Discussion

Three separate survey studies (the web survey, the street survey and the POINTED study) have now been undertaken among NSW residents. Despite different methodological approaches, the web survey and the two separate street intercept surveys (the current study and POINTED) attracted a remarkably similar demographic, with similar alcohol, ED and AED use patterns.

The demographics of all samples were similar, with average ages between 22 and 26, and the majority of participants under the age of 30. However, the web survey was a predominantly female sample (almost two thirds) and the street intercept surveys were predominantly male samples (almost two thirds). It is important to bear in mind that these sample are not representative of the NSW population (for example, 2011 census data indicates that only 19.7% of the NSW population fall between the ages of 14 and 30, with a median age of 38) as we deliberately and non-randomly targeted AED users and young people who frequent the night-time economy in our sampling strategy.

Over 90% of all samples were current alcohol consumers. It is important to note that levels of alcohol consumption in this sample were significantly higher than levels of alcohol consumption among people of similar age in general population samples such as the National Drug Strategy Household Survey (1). This is most likely an outcome of our targeted sampling towards those who are likely to go out and consume alcohol in the night-time economy, but does provide useful new information about

levels of alcohol consumption among young people in this context, and is likely to be important for understanding increases in alcohol-related emergency department presentations among people aged 16-24 in NSW (4).

The web survey and current street survey both show that of the target demographic (young people in NSW who typically go out), approximately one in two have consumed an ED in the past year (48.9% among street intercept participants and 58.8% among web survey participants) and approximately one in three have consumed an AED in the past year (37.5% among street survey participants and 37.9% among web survey participants). The street survey found that 10% of people had consumed an AED during their current night out, compared with 16% of NSW residents interviewed for the POINTED study, indicating that approximately 10-15% of night-time patrons have consumed an AED on a typical night out in NSW.

Consistent with the international literature, males consumed significantly greater amounts of AEDs than females in all samples. However, while a larger proportion of participants aged 18-25 reported having consumed AEDs, there was no difference in the amount of AEDs consumed in a given session across age groups amongst those participants who did consume them. People who were not in steady relationships and were current tertiary students were also more likely to consume AEDs. The web-survey findings revealed that Sydney residents were less likely to consume AEDs than residents in Newcastle and other areas. However, when talking to those on the street, rates of AED use were consistent across nightlife locations in Sydney, Newcastle and Orange. This suggests that a larger percentage of young people living in regional areas may consume AEDs, but there are similar rates of AED use in the night-time economy across geographic locations in NSW.

These results provide unique and valuable new data regarding the prevalence of AED consumption and rates of use, by investigating both typical and maximum levels of consumption among young people who consume alcohol regularly. Consistent with the international literature, web survey participants reported consuming 6.0 alcoholic drinks and 3.0 EDs in typical AED sessions, and similarly, street survey participants reported consuming 8.0 alcoholic drinks and 3.5 EDs during typical AED sessions. This means that AED consumers are exceeding the daily recommended levels of EDs set by the Australian Food and Drug Administration (15) on a typical night out. Frequency of AED consumption was higher amongst participants in the street survey (with almost half consuming AEDs monthly or more compared with 80% of web survey participants consuming AEDs monthly or less), which is unsurprising given they were sampled from night-time entertainment areas. Both the street survey and the POINTED sample saw AED use increase above two AEDs per person between 10-11pm, and both did not drop below this level for the remainder of the night, with levels of AED use highest between 1am-2am.

Of concern was the high rate of AED use reported by 16-17 year olds in this street survey component of the study. Participants of this age group reported 5.4 EDs per AED session, which was almost two EDs more than older age groups. In addition, 16-17 year olds in the street survey reported the highest amount of alcohol in a typical AED session (10.6 drinks). When considering this finding it is important to bear in mind that 16-17 year olds comprised only 3.4% of the street sample and people of this age

group who are on the street late at night are likely to be a 'riskier' demographic of young people; however, more research on AED use is needed among young people to contextualise this finding.

One of the key findings of the web and street survey was the difference in alcohol consumption between and within groups. In both the web survey and street survey, between groups analyses showed that AED users consumed more alcohol, were more likely to use illicit drugs, were more likely to engage in risk taking and were more likely to be involved in incidents of aggression. This is consistent with POINTED findings. However, within group analyses found that AED users consumed more alcohol, more illicit drugs and were involved in more aggressive incidents during "alcohol only" sessions than AED sessions. This significantly contributes to the international literature, which has been conflicted on this issue, as described in the literature review. Among AED users, those who reported mixing greater than two standard energy drinks in typical session reported a significantly higher number of risk taking behaviours than those who consumed two or less EDs (5.8 risk-taking events versus 3.2). While this does not infer causation, objective measure of risk-taking following AED consumption will help to shed light on these findings.

Popular motivations for consumption were consistent between all three samples, with the most commonly reported motivations being taste, wakefulness and energy. This is consistent with the main reasons identified for consuming AEDs in international samples; however, other motivations such as increasing or modifying type of intoxication, noted in international literature, were infrequently reported.

Commonly reported side effects were similar between all three samples, most notably increased reports of racing heart and heart palpitations when compared to alcohol consumption alone. This is consistent with international literature; however, 'worse hangover' and sleeping difficulties, which have been commonly reported in other samples, were not reported in this study to the same magnitude. Of particular interest, 'visual disturbances' in the days following AED use was the most commonly side effect in the web survey, reported by 40% of AED users, although not reported in the street intercept survey. Importantly, side-effects relating to AED use were most commonly reported after consumption of between 4-6 AEDs and some side-effects changed in nature at this point – with effects such as increased rate of speech, slurred speech, dizziness and decreased motor coordination becoming more common during session of AED use at these consumption levels; and racing heart/heart palpitations and gastrointestinal issues becoming more common in the days following AED use after these consumption levels.

#### **4.6.1 Limitations**

Although portal or patron interviews have substantial benefits in terms of investigating people who are patronising the night-time economy, a number of limitations should be noted. Firstly, such surveys are not generalisable to all people who attend licensed venues. Secondly, as potential participants were in the middle of a night out we could only collect information about their night until that point. Thirdly, interviews were conducted within a comparatively public environment, and therefore interviews were necessarily kept short, were not suitable for in-depth questions and were not of a highly personal

nature. Finally, as with all survey methods, there was no way to ensure participants were telling the truth. As such, figures reported as prevalence and quantities are estimates only, and may be influenced by recall bias or participants withholding/exaggerating information. Prior experience with the POINTED project has highlighted the difficulty inherent in obtaining an accurate estimate of consumption prevalence, particularly in relation to illicit substance use.

Web survey data is less influenced by these factors due to the increased anonymity offered by the interface, but is more vulnerable to recall bias. As participants were being asked to recall session over the past 12 months, the potential exists for inaccuracies. Further, the sample is not representative of the NSW population because young AED users were deliberately and non-randomly targeted through recruitment. The length of the survey and the complexity of the questions also resulted in a lower overall response and completion rate compared to the street intercept approach. Further, females were over-represented in the web-sample (and males over-represented in the street sample), as were respondents in Newcastle and surrounding districts in the web-sample due to a successful email campaign through the University of Newcastle.

#### **4.6.2 Key Findings and Recommendations**

*Finding 1:* It appears that people who consume AEDs are higher-risk individuals; they drink more alcohol, use more illicit drugs, experience more aggression and take more risks. However, our data indicates that this is not due to the consumption of AEDs. Our within groups analyses show that all of these variables occur at a higher rate when AED users consume alcohol alone. This is consistent with some international literature (i.e., 129). However, given that AED use is associated with a range of negative side effects, future research should qualitatively seek to investigate the attraction of AED use amongst high-risk individuals.

*Finding 2:* AED consumers identified night life areas as the most popular contexts for consumption (as opposed to EDs unmixed and alcohol only, which were used in a variety of contexts aside from night-time entertainment districts), and many also identified that their consumption of AEDs reduced when they no longer 'went out' as frequently (and may also explain why AED use decreased with age). This most likely explains why rates of use were higher among younger people and calls to NSWPIC and presentations to emergency departments were higher among young people.

*Finding 3:* Survey and experimental findings revealed that AED users experienced physical health side effects during sessions of use, such as increased heart rate and heart palpitations, which are most likely the result of excessive caffeine intake. These harms were most commonly reported after consumption of between 4-6 AEDs. Other acute side effects included agitation and headaches; and visual disturbances and hangovers in the days following AED consumption. Survey findings also revealed that knowledge of side effects predicted reduced use of AEDs. As such, we recommend a range of activities to raise awareness of the potential side effects of AED use. These include:

- Media campaigns raising awareness about the harms of excessive alcohol consumption and the potential for energy drinks to contribute to this, targeted at the demographic of consumers using AEDs frequently at high levels – people aged 18-25 years, particularly young males.

This might include television advertisements, billboards or other forms of media. A cost effective way of doing this would be to add energy drink information to an existing alcohol campaign rather than running a separate campaign.

- Given that AEDs are most commonly consumed in licensed venues, this is an ideal location for targeted advertising. We recommend that posters should be distributed to venues for placement in key locations such as toilets, containing information about the potential risks associated with combining alcohol and energy drinks.
- Use of AEDs was high among 16-17 year olds indicating that prevention and health promotion messages in schools is warranted. Adding an AED component to existing drug education programs offered in schools will be an effective way of disseminating messages around potential harms of use.
- Information should be included on the packaging of EDs that allow consumers to purchase over the recommended daily intake (e.g., 1.25L bottles, 4 packs/6packs, etc.) warning of the 'high caffeine content' (similar to European and Canadian requirements).

*Finding 4:* 40% of web survey participants who used AEDs reported visual disturbances the following day. This finding warrants further research to explore the nature and extent of the visual disturbances, how they might impact driving and similar tasks, whether they are indicative of more permanent damage and the doses of both alcohol and EDs associated with these disturbances. We recommend further research in this area which includes replication of the survey in population samples to confirm the frequency and extent of this side effect, experimental research to examine pathways and aetiology of onset, and qualitative research to explore the nature, severity and effects of this side effect.

## 5. EXPERIMENTAL FINDINGS

### 5.1 Introduction

As discussed in the literature review, researchers generally claim caffeine as the core psychoactive ingredient facilitating the stimulatory effect of EDs, and independent administration of caffeine has been shown to decrease fatigue and improve alertness, reaction time (RT), accuracy, memory, and vigilance. Research also generally supports that ED consumption facilitates selective attention, vigilance, verbal reasoning, psychomotor performance, and driving performance, as well as heightening stimulation and energy and reducing mental fatigue and subjective sleepiness, relative to placebo and control beverages.

As also previously discussed, survey research has indicated increased behavioural risk-taking by ED users; however, conclusions regarding the casual link between ED consumption and increased risk-taking cannot be inferred as individual differences (e.g., trait impulsivity) between ED and non-ED consumers may explain this discrepancy in risk-taking behaviour. Furthermore, the risk-taking behaviour may not be pharmacologically linked to ED consumption, as the behaviours reported do not necessarily occur whilst under the influence of EDs.

Other potential adverse outcomes of ED use include physiological side-effects such as headaches, heart palpitations, and jolt and crash episodes. Despite these self-reported outcomes, there has been limited objective measurement of physiological changes (e.g., heart rate (HR), blood pressure (BP)) post-ED ingestion. One study found that ingestion of two primary ED ingredients, caffeine and taurine, resulted in a significant decrease in heart rate and increase in mean arterial BP (183), while another reported no significant difference in HR, systolic and diastolic BP, or pulse pressure between active and placebo ED conditions (117). The lack of consistency between self-report and objective physiological outcomes, and disparity in results between laboratory-based studies, suggests that further research regarding the physiological outcomes of ED ingestion is required.

In addition to ED harms, combining alcohol with EDs has been argued to potentially cause additional harms by creating a state of 'wide-awake drunkenness', whereby consumers report lower alcohol-induced impairment relative to when consuming alcohol alone. The stimulatory nature of ED may mask the depressant effects of alcohol which act as a subjective indicator of the level of intoxication (95). Consequently, AED consumers may have a reduced ability to accurately estimate their intoxication, causing underestimation of impairment and overestimation of their ability to successfully perform a range of tasks.

However, there has been limited research objectively assessing whether AED leads to: (i) subjective underestimation of intoxication, and (ii) increased impairment of performance on tasks known to be affected by intoxication (e.g., cognitive and motor performance). To date, there have only been four small human studies assessing these outcomes which have generally shown no impact of AED relative to alcohol on ratings of intoxication and equivocal results regarding objective performance outcomes (74, 95, 157, 159). However, there have been several methodological limitations raised, with conclusions of AED-induced changes in perceived intoxication following examination of

descriptive data rather than inferential statistics (74) and in the absence of a baseline assessment of subjective state (159). Furthermore, these studies have focused on performance-based measures of intoxication; there has been relatively no research assessing AED-induced changes in the physiological state of intoxication (e.g., heart rate, blood pressure), despite (i) the aforementioned self-reported negative side-effects of EDs and (ii) the fact that consumers self-report higher odds of side-effects related to over-stimulation (e.g., heart palpitations) when consuming AED relative to alcohol (129). However, the primary limitation of these previous studies relates to the doses investigated. Previous survey research has shown that Australian consumers typically consume 7.1 standard alcoholic drinks and 2.4 standard EDs when using AEDs (129); a similar finding was reported in the survey results of this study (Chapter 4). Despite this, the previous research has involved administration of a standard low ED dose (one standard ED, approximately 250mL per 70kg). As the potential for interactive effects are inflated at higher doses, research needs to extend into the higher dosage domain to increase the ecological validity and inform policy development.

The main concerns surrounding AED consumers' potential misperception of intoxication is that this state may result in excess consumption of alcohol, a longer drinking period, and/or an increased likelihood of engaging in risk-taking behaviours (161). In regards to the effect of AED on risk-taking, field research by Thombs et al. (127) showed that bar patrons who consumed AEDs had a four-fold increased likelihood of reporting an intention to drive a motor vehicle while intoxicated than those who had not consumed AED. Similarly, a survey of American college athletes showed that they reported expecting to engage in more risky behaviour during AED sessions than alcohol sessions (124). However, these studies did not require reporting of actual engagement in risk-behaviours; the former study entailed an indication of intention while the latter asked participants to report their general expectations. Furthermore, the former study involved comparison of AED versus non-AED consumers, meaning that the outcomes might be due to individual differences between consumers, such as level of trait impulsivity, rather than due to the direct effects of AED. Assessment of risk-taking using ecologically valid, objective measures (e.g., driving simulator tasks) and a within-subjects design in a laboratory-based setting would allow for measurement of actual risk-taking behaviour while controlling for individual differences between consumers.

## 5.2 Objectives

Despite an increasing focus on the harms associated with AED use, there is a current paucity of research examining whether AED, relative to alcohol, causes: (i) subjective underestimation of intoxication, and (ii) increased or decreased impairment of performance on outcomes known to be impacted by alcohol (e.g., cognitive and motor performance). Those few studies which have been conducted are restricted by methodological limitations, particularly the use of a single low ED dose, which minimises the generalisability of outcomes to 'real-life' AED consumption. Furthermore, there has been relatively no consideration of the physiological intoxication outcomes of AED consumption, despite the higher self-reported incidence of side-effects related to over-stimulation post-AED use. Finally, there is no research objectively assessing the effect of any discrepancies in intoxication on risk-taking behaviour, even though the literature outlining self-reported risk-taking by consumers is

equivocal regarding whether AED increases rates of risk-taking relative to alcohol. Consequently, the aims of the present study were to look at the interactive effect of alcohol and EDs at different doses to examine if:

1. AED changes blood alcohol concentration (BAC<sup>13</sup>), the primary measure of alcohol impairment which reflects the disposition and fate of alcohol in the body, evident via increased or decreased BAC after consuming AED relative to alcohol?
2. AED causes an underestimation of perceived intoxication, as evident via reduced ratings of intoxication after consuming AED relative to alcohol?
3. AED causes an increase or decrease in objective intoxication outcomes, as evident via greater or lesser impairment on cognitive and motor performance outcomes after consuming AED relative to alcohol?
4. AED causes an increase or decrease in physiological indices of intoxication, as evident via an increase or decrease in HR and BP after consuming AED relative to alcohol?
5. AED causes an increase in behavioural risk-taking, as evident via an increase in risky behaviour on a driving simulator task after consuming AED relative to alcohol?

## 5.3 Methods

### 5.3.1 Participants

The sample comprised 30 healthy volunteers (15 males) in order to allow reliable (power = 0.80) detection of an alcohol-ED interaction effect of moderate magnitude (Cohen's  $f=0.20$ ) as statistically significant (alpha = 0.05). Participants were recruited via noticeboard advertisements and print and radio media reports, where they were directed to a secure online survey to register their details and complete a brief screening questionnaire. Recruitment advertisements stated that the researchers were seeking interested people who had consumed alcohol and EDs before to participate in a study examining the independent and combined effects of alcohol and EDs on performance, specifically cognitive, motor, and driving performance. Inclusion criteria pertained to age (20 to 35 years), self-reported normal sleep patterns and normal or corrected-to-normal vision, as well as adequate pre-morbid intelligence (completed Year 12 or equivalent) and English proficiency (English as a first language) to provide informed consent. Additional criteria required that participants held their full driving licence to minimise the impact of experience on driving simulator performance and were regular ED, caffeine, and alcohol consumers, as indicated by (i) minimum consumption of one ED in the preceding month and maximum consumption of one ED per day on average in the preceding month, (ii) consumption of between 4 and 28 caffeinated products in the preceding week, and (iii) minimum consumption of two standard alcoholic drinks in the preceding fortnight.

Exclusion criteria were intended to screen those at increased risk for negative side-effects from the treatment and ensure that outcomes could be causally attributed to treatment administration as opposed to other confounding factors (e.g., other drug use). These criteria included: (i) current

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<sup>13</sup> Blood alcohol concentration was estimated from breath using a breathalyser.

pregnancy or lactation, (ii) current significant medical disorder, (iii) epilepsy or history of any significant neurological condition, (iv) current diagnosis of a significant psychiatric disorder or score of  $\geq 30$  on the Kessler Psychological Distress Scale (K10) (184), (v) history of alcohol or drug abuse or dependence disorder or use of alcohol at hazardous or harmful levels, evident via a score of  $\geq 16$  on the Alcohol Use Disorders Identification Test (AUDIT) (185), (vi) significant intellectual disability or IQ of  $\leq 70$  on the Wechsler Test of Adult Reading (WTAR), (vii) current regular use of tobacco, (viii) illicit drug use in the preceding 14 days, (ix) current use of a contraindicated prescription medication, and (x) participation in a drug study within the preceding three months.

Informed consent was provided prior participation; participants were advised they may receive alcohol (maximum approximately six standard drinks), EDs (maximum approximately three standard 250ml portions) or both during some or all of the sessions. The research protocol was approved by the Human Research Ethics Committee Tasmania Network. Participants were reimbursed \$160 for their participation, with a maximum of \$80 (\$20 per session) task reimbursement. The study was investigator-led with funding for task and participant reimbursement and other materials provided by the New South Wales Ministry of Health.

### **5.3.2 Materials and Apparatus**

#### **Subjective Effects Scale (SES)**

The SES was administered to determine participants' perceived intoxication. Participants rated their current level of intoxication by moving an automated arrow along a 100 mm visual slider; the left anchor (0mm) was designated 'not at all' and the right anchor (100mm) was designated 'very much'. The distance in millimetres from the left anchor provided the item score, with a higher score indicating greater intoxication.

#### **Beverage Rating Scale (BRS)**

The BRS was administered firstly to confirm successful placebo manipulation and secondly as an additional measure of perceived intoxication. Participants reported the perceived alcoholic and ED content of the beverage administered in regards to the number of bottles of beer (375mL containing 4.8% alcohol; 1.4 standard drinks) and number of standard EDs (250mL ED containing 80mg caffeine). This measure was only administered at the conclusion of each experimental session.

#### **Occupational Safety Performance Assessment Technology (OSPAT)**

The OSPAT (186) was administered as an unpredictable measure of tracking performance that required quick reaction time, focused attention, and hand-eye coordination. Participants continually returned an unpredictably moving cursor to the centre of a circular target presented on a screen using a track ball for three 40-second trials. Cursor movement (jitter) was varied based on an adaptive staircase procedure to avoid ceiling effects. The primary outcome was a performance score produced from an algorithm based on reaction time and accuracy; higher scores indicated better tracking

performance. The OSPAT is highly sensitive to detecting the effects of alcohol on performance (187) and is used commercially for fitness-to-work assessment.

### **The Cambridge Neuropsychological Test Automated Battery (CANTAB)**

Three tests were administered from the CANTAB (188): the Reaction Time Index (RTI), Rapid Visual Processing (RVP), and Stop-Signal Task (SST). The CANTAB tests have been validated in behavioural and psychopharmacological studies with animals and healthy human volunteers, in neuro-imaging studies with human volunteers and a wide variety of patient groups.

In the *RTI*, a measure of participants' sensory-motor speeded performance, participants depressed a response pad and touched the circle presented on the screen at a single known location (simple RT), and at one of five locations (choice RT). Thirty trials were conducted for each component. The primary RTI outcomes included simple and choice reaction time (ms), with shorter reaction times indicating better sensory-motor performance.

In the *RVP*, a measure of sustained attention, participants pressed the response pad whenever a sequence of individual digits presented in the centre of the monitor matched one of three target sequences displayed on the right of the screen (2-4-6, 3-5-7, 4-6-8). The individual digits (2-9) were presented at a rate of 100 per minute, with target sequences occurring at a rate of 16 every two minutes. The primary outcome was the mean response latency (ms) (i.e., time taken to press the response pad on identifying the sequence); shorter response latency indicated better sustained attention.

In the *SST*, a measure of participants' ability to withhold an already initiated response, participants pressed the left- and right-hand response button on sighting a left- or right-pointing arrow respectively, withholding their response if they heard an auditory signal after presentation of the arrow. Participants completed five blocks of 64 trials, with the stop cue presented on 25% of trials (blocked so that 4 'stop' signals were presented every 16 trials). The primary outcome was the length of time between the go stimulus and the stop cue at which the subject was able to successfully inhibit their response on 50% of trials; a faster time indicated better response inhibition and less impulsivity.

### **Purdue Pegboard Task (PPT)**

The *PPT* (189) assessed gross movement of fingers, hands, and arms, as well as fine motor movement of fingers during an assembly task. Participants completed two trials with different response requirements using a two-column grooved pegboard. For the 30-second trial, participants picked up and placed as many pins as possible one at a time with their dominant hand in the corresponding (left or right) grooved column (gross motor movement). For the second 60-second trial, participants used both hands in an ordered, continuous motion to create as many assemblies (pin, washer, collar, and washer) as possible (fine motor movement). Participants were awarded one point for each correctly placed pin or part of the assembly respectively. The primary outcome for gross motor movement was the number of pegs placed with the dominant hand; the primary outcome for

fine motor movement was the number of parts assembled. Higher scores indicated better gross and fine motor movement respectively.

### **Balance Task**

The ability to maintain balance was measured using an AMTI AccuSway Plus Force Platform with NetForce software. In a barefoot closed heel stance, participants were instructed to maintain a relaxed posture with their arms resting by their sides while staring ahead at a fixation point for three 20 second trials, with a 20 second break between trials. The displacement of standing centre of pressure (COP) was sampled continuously at 50Hz in anterior-posterior and medial-lateral directions with a cut-off frequency of 10Hz. The primary outcome was the 95% ellipse sway area included in the COP path (cm<sup>2</sup>), that is, the amount of area participants covered while standing. A greater sway area indicated greater instability.

### **Driving Simulator Task**

The driving simulator task was delivered via a state-of-the-art STISIM Drive™ M400 simulator. The simulator consisted of a car unit with an adjustable car seat, seatbelt, dashboard, steering wheel, indicators, brake and accelerator pedal, with a realistic driving scenario displayed across three computer screens (140° view of the driving environment), rear and side mirrors, and auditory feedback provided by speakers (i.e., sound of the engine, braking, speeding through corners and when a collision occurs). The driving task assessed driving performance and driving risk-taking. Participants were provided reimbursement (maximum of \$20) for achieving a time target of 12 minutes for the drive. Participants were instructed to abide by the road rules, follow auditory instructions to turn right at intersections, and hit the brake when a stop sign flashed up to obscure the screen. Stop sign intersections and ambiguous traffic light changes were included in the drive. Behaviour was manipulated by including a \$1 AUD penalty per speed violation and per minute in excess of the time target; accidents/collisions and traffic light and stop sign violations incurred a \$2 AUD penalty. The primary outcome indicative of driving performance was the percentage of time during the drive spent out of the lane (i.e., amount of time participant drove over the dividing line or road edge line); a higher percentage indicated poorer driving performance. The primary outcome indicative of risk-taking was the percentage of time in exceeding the speed limit; a higher percentage indicated more risk-taking.

### **Heart Rate (HR) and Blood Pressure (BP)**

HR (pulse) and systolic and diastolic BP were measured using an Association for the Advancement of Medical Instrumentation (AAMI) standard Omron portable automatic professional digital BP system. Three recordings were taken at 1 minute intervals with a 10 minute rest preceding recordings; systolic and diastolic BP and HR (beats per minute) were averaged over the three measurements.

### **5.3.3 Procedure**

Eligible participants were booked for a 60 minute screening and familiarisation session following completion of the initial online screening questionnaire. Following provision of informed consent,

participants completed those screening measures which could not be administered via phone (K10, WTAR, and AUDIT).

Once inclusion was confirmed, participants were weighed for substance administration purposes and then completed a Caffeine and Energy Drink Use Questionnaire (CEDUQ) to measure average daily caffeine intake (mg) and frequency/quantity of ED consumption.

Participants were provided instruction in the experimental tasks and completed sufficient practice trials to ensure task familiarity.

#### **5.3.4 Study Restrictions**

All experimental sessions were conducted at the School of Psychology, University of Tasmania, and began between 8:00am and 5:00pm with a minimum of two and maximum of 14 days separating sessions. Session start times differed for each participant, with sessions typically commencing at 9:00am, 12:30pm or 4:00pm. Participants were instructed to abstain from food for 4 hours, caffeine products for 8 hours, and medication (except contraceptives) and alcohol for 24 hours; abstinence from tobacco and illicit drugs was required for the duration of participation. A standard light meal devoid of high-fat or dairy products was advised prior to the fasting period and participants were asked to limit their water intake and avoid vigorous exercise in the 4 hours prior to the sessions. Participants were instructed to consume a standard breakfast bar (provided in the familiarisation session) 90 minutes prior to commencing each session.

#### **5.3.5 Assignment of Treatment Order**

Participants were randomly assigned a treatment code counterbalanced for sex corresponding to an alcohol group assignment (placebo, moderate, or high alcohol group) and counterbalanced ED treatment administration order. The schedule was prepared by a research associate not involved in the study. While ED administration was double-blind, only the participant was blind to alcohol administration.

#### **5.3.6 Experimental Sessions**

Table 34 outlines the protocol for the experimental sessions. On arrival, participants completed a declaration confirming compliance with study restrictions. In order to establish a baseline, participants completed the SES and HR and BP were recorded. Participants were then administered a different ED treatment in combination with their allocated alcohol dose in each of the four sessions:

- Allocated alcohol dose + three standard 250mL EDs (*combined condition: high*)
- Allocated alcohol dose + two standard 250mL EDs (*combined condition: medium*)
- Allocated alcohol dose + one standard 250mL ED (*combined condition: low*)
- Allocated alcohol dose + 0mL ED (*alcohol condition*)

The dose was split into three portions and served in lidded opaque cups. Participants had five minutes to orally consume each portion. As retention of mouth alcohol can influence breathalyser sensitivity (190) participants were instructed to avoid retaining the beverage in their mouth for longer than five

seconds. However, they were encouraged to drink the beverage at a steady pace throughout the administration period. Participants were provided a standard amount of still water (250ml) for the duration of the session. Participants had a 15 minute absorption period following the beverage consumption time. Thirty minutes post-beverage initiation, participants completed the SES and HR and BP were recorded. The objective intoxication measures were commenced 50 minutes after beverage initiation; at the conclusion of testing (170 minutes) the SES and BRS were administered and HR and BP were measured. BAC measurements were taken with an Alcolizer HH-2 breathalyser at the start of each task.

*Table 34. Protocol for experimental sessions*

<b>Time</b>	<b>Task</b>
Baseline	SES/HR/BP/
0 minutes	Beverage Portion 1
5 minutes	Beverage Portion 2
10 minutes	Beverage Portion 3
30 minutes*	SES/HR/BP
50 minutes*	OSPAT
55 minutes*	RTI, RVP, SST
105 minutes*	PPT
110 minutes*	Balance
150 minutes*	Driving Task
170 minutes*	SES/BRS/HR/BP

Note. \* indicates that BAC measurements were taken prior to commencing the task. HR: heart rate; BP: blood pressure; SES: Subjective Effects Scale; OSPAT: Occupational Safety Performance Assessment Technology; RTI: Reaction Time Index; RVP: Rapid Visual Processing; SST: Stop-Signal Task; PPT: Purdue Pegboard; BRS: Beverage Rating Scale.

At the end of testing, participants remained in the laboratory until providing two BAC measurements of 0.03% or less within 15 minutes. Participants were instructed to avoid operating machinery or consuming alcohol for 4 hours after each session. At the conclusion of testing, participants were debriefed and reimbursed \$160.

### **5.3.7 Administered Treatments**

The *active alcohol doses* for the moderate and high alcohol group, 0.50g/kg and 0.65g/kg (37.5% a/v Smirnoff Red Label No. 21 vodka), were chosen to result in peak BACs of approximately .050% and .080%, the Australian legal limit and the New Zealand and United States legal limits for driving under the influence respectively. Vodka was chosen as the alcohol mixer as it is the most popular AED mixer (128) and the optimal spirit for blinding due to its relatively inconspicuous flavour. The dose was decreased to 85% for females, as women generally record higher and more prolonged BAC (191,

192). The *placebo alcohol dose* was achieved by floating 3ml on each beverage portion, with a light alcohol mist sprayed over the beverage container.

The *active ED conditions* comprised: (i) one standard 250mL ED, (ii) two standard 250mL ED, and (iii) three standard 250mL ED. The former two doses were supplement with soda water (500mL and 250mL) to ensure a consistent beverage volume across sessions. Red Bull® was administered as the active ED mixer as: (i) Red Bull® holds the greater proportion of the ED market, and (ii) 89% of Australian AED consumers reported typically using this ED as their mixer of choice during AED sessions (128). This ED contains approximately 80mg caffeine, 1000mg taurine, 60mg glucuronolactone, and 27g sugar per 250mL portion. The *placebo ED dose*, 750mL soda water, comprised the fourth condition. All ED doses were supplement with Torani® sugarfree English Toffee and Black Cherry syrups to match the taste, appearance, and smell of the beverages.

### 5.3.8 Analyses

BAC was not recorded for two participants in the moderate alcohol group at 30 minutes ( $n=8$ ), and one participant in the placebo alcohol group had missing BRS data ( $n=9$ ), and one participant in the high alcohol group had missing OSPAT data ( $n=9$ ), all due to technical malfunction. One participant in the placebo alcohol group had missing data for the driving simulator measure of risk-taking due to misunderstanding of task instructions ( $n=9$ ).

For the SES, diastolic and systolic BP, and HR, the change in rating/recording when taken at baseline compared to 30 minutes after commencing beverage consumption was calculated to control for differences at baseline. Statistical analyses were conducted using IBM SPSS Statistics 19.

Descriptive statistics were calculated for the sample characteristics and one-way ANOVAs were conducted to ensure that the alcohol groups did not significantly differ in regards to their composition.

Descriptive statistics were calculated and ANOVAs were conducted for: (i) perceived intoxication outcomes, (ii) objective intoxication outcomes, (iii) physiological intoxication outcomes, and (iv) behavioural risk-taking outcomes, to statistically determine the following:

1. If there was a dose-dependent impact of alcohol on the outcomes (i.e., did the outcomes differ according to whether a placebo, moderate or high alcohol dose was consumed, regardless of ED intake?), we averaged the outcomes across the sessions when participants had no ED, one ED, two ED, and three ED for each alcohol group separately (placebo, moderate, and high alcohol group), in order to have an overall estimate of the outcome for the each alcohol dose groups. This is referred to in the results as “averaging across the ED conditions”.
2. If there was a dose-dependent impact of ED on the outcomes (i.e., did the outcomes differ according to whether no ED (placebo), one standard ED, two standard ED, or three standard ED were consumed, regardless of alcohol intake)? We averaged the outcomes across the alcohol groups for when participants no ED, one ED, two ED, and three ED, in order to have an overall estimate of the outcome when each ED dose was consumed. This is referred to in the results as “averaging across the alcohol groups”.

3. If there was an interactive effect of alcohol dose and ED dose (i.e., did the outcomes differ between the alcohol groups according to the volume of ED consumed)?

Analyses revealed that there were differences in BAC when alcohol was consumed due to the amount of ED consumed, meaning that any ED dose-dependent differences in outcomes might reflect pre-existing differences in BAC. Consequently, we also ran ANCOVAs using the recorded BAC at the time of the measurement as a covariate to determine:

4. If there were any dose-dependent effects of ED on outcomes after statistically controlling for the differences in BAC for: (i) the moderate alcohol group and (ii) the high alcohol group?

Finally, as previous research shows sex differences in the rate of alcohol absorption and elimination and in the impact of alcohol on performance outcomes (192, 193), we conducted ANOVAs to determine:

5. If males and females differed in their outcomes according to the amount of alcohol and/or ED consumed?

Where the assumption of sphericity was violated, the Huynh-Feldt correction was applied where  $\epsilon \geq .75$ ; and the Greenhouse-Geisser correction was applied where  $\epsilon \leq .75$ . Theoretically significant treatment effects were followed up by independent sample *t*-tests (alcohol group) or within-subjects *t*-tests (ED dose). Significance levels were maintained at  $p < .050$ . The significance level (*p* value, reported as 'ps' in the results) represents the probability of obtaining an outcome which is due to chance or error; *p* values less than .050 mean that we can be 95% confident that the difference in outcomes (e.g., the difference between the mean performance score after consuming AED and after consuming alcohol without ED) is due to an actual difference due to the treatment and not due to chance or error. The cut-off level chosen for the current study ( $p < .050$ ) is the conventional cut-off used in research. Effect sizes were calculated where  $p < .010$  using Hedges' *g*. The effect size (Hedge's *g*, reported as 'gs' in the results) is important to consider in conjunction with the *p* value, as it indicates the magnitude of the difference between the two comparison points (e.g., the magnitude of difference between the mean performance score after consuming AED and the mean performance score after consuming alcohol). It should be noted that a moderate magnitude effect ( $g = 0.4-0.8$ ) would very likely have a perceivable impact on behaviour. While a small magnitude effect ( $g < .04$ ) indicates real changes in behaviour, it is not likely that a small magnitude effect would have practical implications or reflect a noticeable difference in outcomes in real life.

## 5.4 Results

### 5.4.1 Sample Characteristics

The final sample comprised 30 participants (15 males), with 10 participants (5 males) per alcohol treatment group. It should be noted in advance that the placebo, moderate and high alcohol groups did not differ significantly in regards to any characteristics ( $ps > .141$ ). These results confirm that the random allocation of participants was successful and thus it is unlikely that any differences in

outcomes between the groups are due to the composition of the group as opposed to treatment effects.

The demographic composition of the whole sample and each alcohol group is displayed in Table 35. Participants were typically aged in their mid-twenties, evidenced average premorbid intellectual functioning (WTAR) and reported a low level of psychological distress (K10). While two-thirds were currently studying for post-secondary qualifications, nearly half had completed a post-secondary qualification (trade and/or tertiary) at the time of participation.

*Table 35. Demographic characteristics of the sample according to alcohol treatment group (standard deviation in parentheses)*

	<b>Placebo Alcohol Group</b>	<b>Moderate Alcohol Group</b>	<b>High Alcohol Group</b>	<b>Overall Sample</b>
Mean Age (years)	23.6 (3.3)	25.4 (3.4)	25.0 (3.7)	24.7 (3.4)
Mean Weight (kg)	80.4 (21.8)	68.5 (12.0)	88.1 (40.3)	78.07 (27.0)
Mean WTAR IQ	104.2 (9.9)	108.5 (11.0)	112.0 (11.0)	108.2 (10.8)
Mean K10 score	13.3 (3.9)	11.7 (1.6)	13.8 (2.6)	12.9 (2.9)
Current studying post-secondary qualifications (%)	70.0	50.0	80.0	66.7
Completed post-secondary qualifications (%)	30	70	40	46.7

*Note.* Kessler Psychological Distress Scale (K10) score range is 10 to 50, with scores of 30 or higher indicative of a moderate to severe mental illness; Wechsler Test of Adult Reading (WTAR) standardized score is 100, with higher scores indicative of higher levels of general premorbid intellectual functioning.

While AUDIT scores ranged from 3-15, participants typically did not score above the AUDIT cut-off indicative of potential alcohol abuse (score of 8 or higher) (Table 36) (185). Two-thirds of the sample reported typical alcohol intake which fell within the low risk guideline of four standard drinks to minimise alcohol-related injury (194); almost one-fifth of the sample consumed between 5 and 9 standard drinks and one-fifth typically ingested 10 or more standard drinks. As evident in Figure 59, participants reported typically consuming alcohol on a fortnightly to thrice weekly basis in the preceding year. This is broadly consistent with the drinking patterns reported in the general Australian population, with 44% of 20-29 year old Australians consuming alcohol on a weekly basis (195). Participants' self-reported typical ED intake fell within the recommended maximum daily guidelines of two standard 250mL EDs (Table 36) (15); these beverages were generally consumed on a monthly to weekly basis by participants in the preceding month (see Figure 60). Participants' reported a moderate daily average caffeine intake, equivalent to approximately two cafe-style cappuccinos (i.e., 136mg/220mL).

Table 36. Self-reported alcohol, caffeine and energy drink consumption patterns of the sample according to alcohol treatment group (standard deviation in parentheses)

	Placebo Alcohol Group	Moderate Alcohol Group	High Alcohol Group	Overall Sample
AUDIT score <sup>a</sup>	7.8 (4.2)	6.3 (1.6)	7.4 (3.7)	7.2 (3.3)
Average standard alcohol intake <sup>a</sup> (%)				
1 or 2 drinks	20.0	40.0	20.0	26.7
3 or 4 drinks	30.0	50.0	40.0	40.0
5 or 6 drinks	20.0	10.0	10.0	13.3
7 to 9 drinks	10.0	0.0	30.0	13.3
10 or more drinks	20.0	0.0	0.0	6.7
Average standard ED intake <sup>b</sup>	1.3 (0.7)	1.2 (0.4)	1.6 (0.8)	1.4 (0.7)
Maximum standard ED intake <sup>b</sup>	2.6 (1.2)	2.9 (2.6)	1.7 (0.8)	1.7 (0.8)
Average caffeine intake <sup>c</sup> (mg/day)	341.0 (176.3)	230.4 (107.4)	260.1 (199.2)	277.2 (166.7)

Note. Alcohol Use Disorders Identification Test (AUDIT) score range is 0 to 40, with a score of 16 or more indicative of hazardous or harmful alcohol use; definition of a standard energy drink (ED) was 250 ml ED containing approximately 80 mg caffeine; <sup>a</sup> reflects consumption in the preceding 12 months; <sup>b</sup> reflects consumption in the preceding month; <sup>c</sup> reflects consumption in the preceding week.

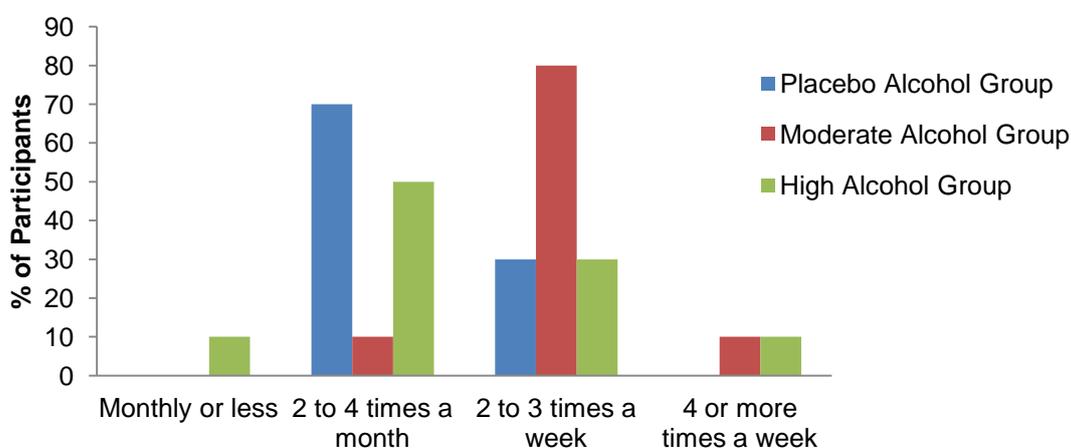


Figure 59. Typical frequency of alcohol use in the preceding 12 months according to alcohol treatment group

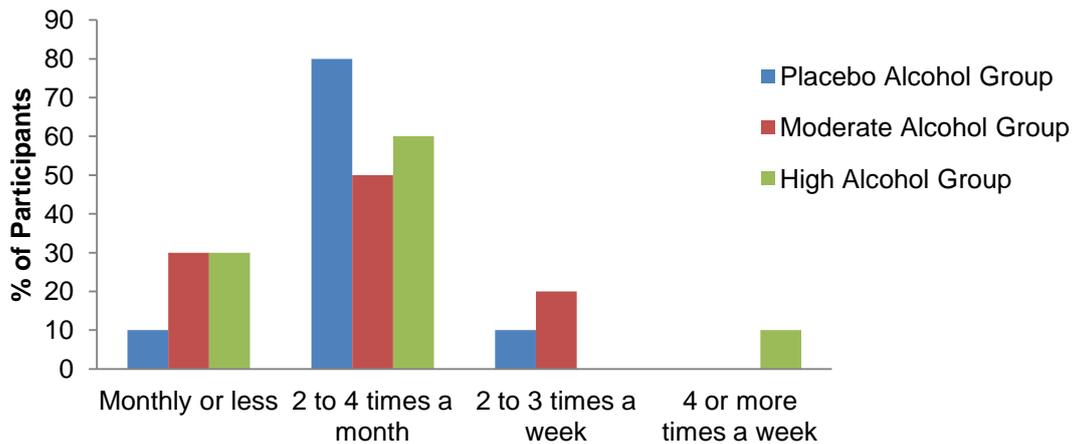


Figure 60. Typical frequency of ED use in the preceding month according to alcohol treatment group

#### 5.4.2 Blood Alcohol Concentration (BAC)

Mean BACs for the moderate and high alcohol groups are displayed in Figure 61; there were no detectable BACs recorded for the placebo alcohol group.

Peak BAC was .068% at 30 minutes and .080% at 50 minutes for the moderate and high alcohol groups respectively (when no EDs were consumed). A 4 (Time: 30, 55, 105, and 150 minutes) x 4 (ED: 0mL, 250mL, 500mL, and 750mL) ANOVA revealed that the effect of ED on BAC at each time point for the moderate and high alcohol group was not consistent,  $F(4, 61)=3.628$ ,  $p=.013$ . As such, follow-up analyses were conducted at each time point for each alcohol group to determine the effect of different ED volumes on BAC.

##### What was the effect of three standard EDs on BAC?

There was a significant large magnitude *decrease* in BAC across all time points when the moderate alcohol dose was consumed with three standard EDs compared to when the moderate alcohol dose was consumed without any EDs ( $ps<.004$ ,  $gs>1.19$ ). There was also a *decrease* in BAC at three of the four time points (30, 55, and 105 minutes) when the high alcohol dose was consumed with three standard EDs compared to when the same alcohol dose was consumed without any EDs ( $ps<.034$ ,  $gs>.040$ ). It should be noted that the decrease in BAC following consumption of three standard EDs with the high alcohol dose was of a moderate to large magnitude and at 150 minutes trended towards statistical significance ( $p=.065$ ,  $g=0.38$ ). These results suggest that BAC is lower after consuming three EDs with a moderate or high alcohol dose compared to when the same alcohol dose is consumed without any EDs.

##### What was the effect of two standard EDs on BAC?

There was a significant moderate magnitude *decrease* in BAC when the moderate alcohol dose was consumed with two standard EDs compared to when the moderate alcohol dose was consumed without any EDs ( $ps<.040$ ,  $gs>0.64$ ). It should be noted that at the final time point (105 minutes) the decrease in BAC trended towards statistical significance but was still a moderate magnitude

difference ( $p=.105$ ,  $g=0.57$ ). There was also a moderate to large magnitude *decrease* in BAC when the high alcohol dose was consumed with two standard EDs compared to when the same alcohol dose was consumed without any EDs ( $gs>0.53$ ). However, with the exception of the final time point ( $p=.009$ ), this difference in BAC generally trended towards statistical significance ( $p=.061$  to  $.084$ ). Overall, these results indicate that BAC is generally lower when a moderate or high alcohol dose is consumed with two standard EDs compared to when it is consumed without an EDs.

#### **What was the effect of one standard ED on BAC?**

There was a moderate magnitude *decrease* in BAC when the moderate alcohol dose was consumed with one standard ED relative to when the moderate alcohol dose was consumed without EDs ( $gs>0.44$ ). However, this difference in BAC occurred only at the two middle time points (55 and 105 minutes) and trended towards statistical significance ( $p=.075$  and  $p=.084$  respectively). There was no significant impact of one standard ED on BAC following the high alcohol dose.

#### **What were the dose-dependent effects of ED on BAC?**

There was some evidence of BAC differences according to the amount of ED dose co-ingested. There were statistically significant moderate to large magnitude *decreases* in BAC across all time points when the moderate alcohol dose was consumed with three standard EDs compared to when it was consumed with two standard EDs ( $ps<.043$ ,  $gs>.062$ ) or one standard ED ( $ps<.007$ ,  $gs>0.89$ ). There was also a moderate magnitude *decrease* in BAC when the moderate alcohol dose was consumed with two standard EDs relative to one standard ED ( $g=0.68$ ). However, this difference in BAC occurred only at 55 minutes and trended towards statistical significance ( $p=.065$ ).

For the high alcohol dose group, there were no significant differences in BAC for co-ingestion of three versus two standard EDs. A moderate magnitude *decrease* in BAC was evident when the high alcohol dose was consumed with two standard EDs relative to one standard ED ( $g=0.43$ ). However, this difference trended towards significance ( $p=.050$ ) and only occurred at the final time point (150 minutes).

#### **Were there sex differences in BAC?**

Analyses revealed that there were no sex differences in BAC at each time point according to the amount of ED consumed ( $ps>.169$ ).

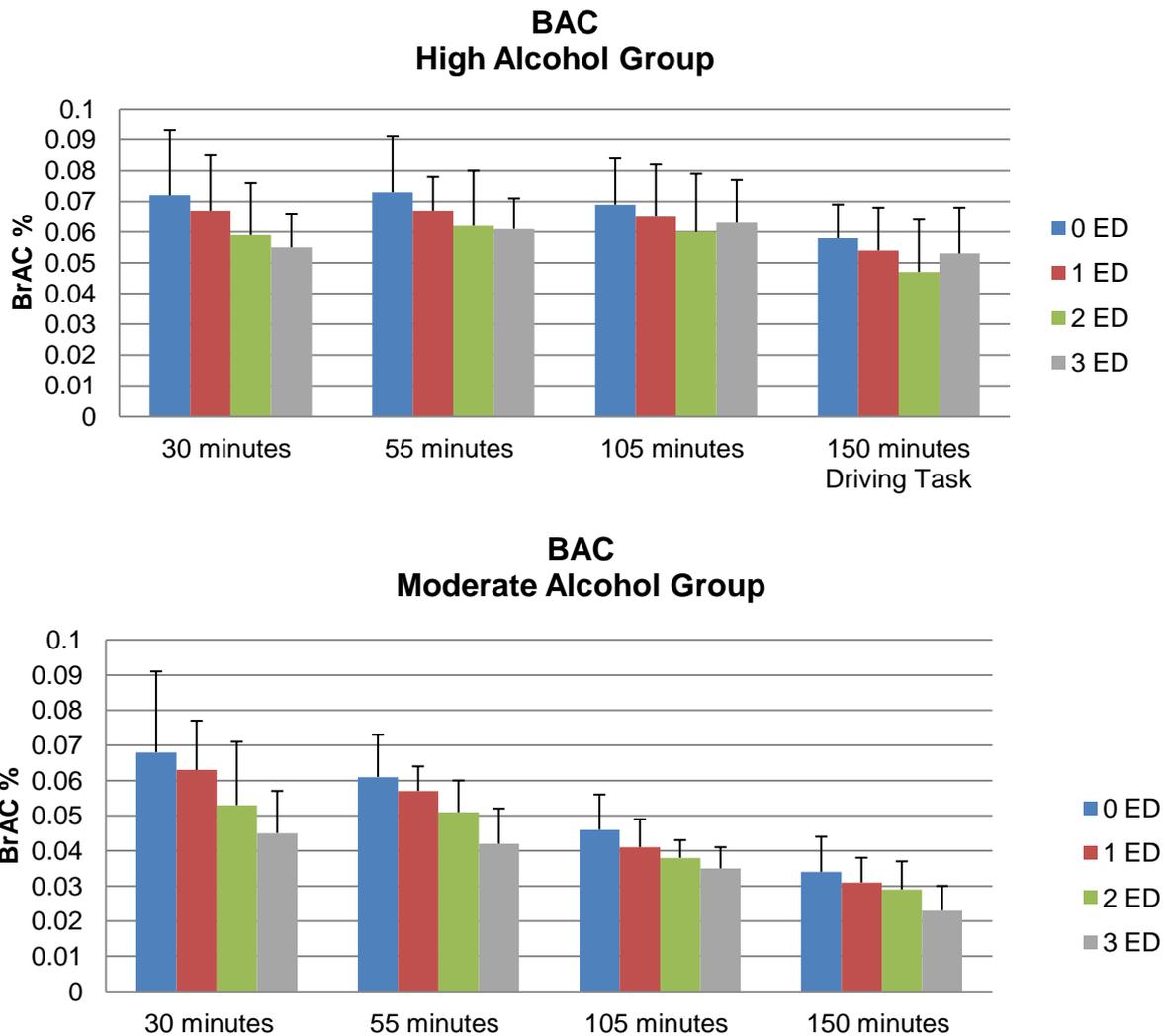


Figure 61. Mean BAC at each time point for the moderate (lower panel) and high (upper panel) alcohol dose groups according to the number of EDs co-ingested (error bars depict the standard deviation)

### Summary of BAC Outcomes

In summary, a lower BAC was evident when consuming the moderate alcohol dose with ED relative to without ED, particularly when ingesting higher ED quantities. Specifically, the moderate alcohol group had a peak BAC of .068% at 30 minutes when the alcohol dose was consumed without EDs compared to a peak BAC of .063%, .053%, and .045% when the alcohol dose was consumed with one, two, and three standard EDs respectively. This pattern of results was also generally evident when the high alcohol dose consumed, but only when the alcohol dose was consumed with two standard EDs (the recommended maximum daily ED intake) or three standard EDs. Specifically, the high alcohol group had a peak BAC of .073% at 55 minutes when the alcohol dose was consumed without EDs compared to a peak BAC of .067%, .062%, and .061% when the alcohol dose was consumed with one, two, and three standard EDs respectively.

There was evidence that the volume of ED impacted differentially on BAC, with lower BAC recorded when three standard EDs were co-ingested with alcohol relative to one or two standard EDs. However, this effect was typically only evident when the moderate alcohol dose was consumed; there was limited evidence that BAC differed after the high alcohol dose according to whether one, two, or three standard EDs were consumed.

### 5.4.3 Perceived Intoxication

Figure 62 displays the mean change in subjective rating of intoxication made at baseline relative to 30 minutes after commencing beverage consumption for each alcohol group according to the amount of ED co-ingested; the higher the change in rating the greater the perception of intoxication.

#### Manipulation check: did subjective intoxication increase with increasing alcohol?

Subjective intoxication ratings were significantly impacted by alcohol dose,  $F(2, 27)=9.994$ ,  $p=.001$ . There was a large magnitude increase in intoxication ratings from baseline to 30 minutes after beverage consumption when the high alcohol dose ( $M=49.4$ ,  $SD=22.7$ ) or the moderate alcohol dose ( $M=33.1$ ,  $SD=20.9$ ) were consumed relative to the placebo alcohol dose ( $M=10.6$ ,  $SD=13.8$ ;  $p<.001$ ,  $g=2.07$  and  $p=.012$ ,  $g=1.27$  respectively), regardless of the ED dose consumed. However, participants did report an increase in intoxication following the placebo alcohol dose, suggesting that the placebo manipulation was successful. Ratings following the high and moderate alcohol doses did not differ significantly ( $p=.112$ ).

#### What were the dose dependent effects of ED on subjective ratings of intoxication?

Subjective intoxication ratings also differed significantly according to ED dose,  $F(3, 81)=4.760$ ,  $p=.004$ , regardless of alcohol group. Participants rated their intoxication as lower after they consumed three standard EDs ( $M=22.1$ ,  $SD=26.8$ ) compared to when they consumed no ED ( $M=37.6$ ,  $SD=33.7$ ,  $p=.004$ ,  $g=0.51$ ), one standard ED ( $M=32.7$ ,  $SD=25.2$ ,  $p=.014$ ,  $g=0.41$ ), or two standard EDs ( $M=31.5$ ,  $SD=27.3$ ,  $p=.038$ ,  $g=0.35$ ). There were no other significant comparisons ( $ps>.176$ ). These results suggest that consumption of a high ED dose may actually lower perception of intoxication relative to when no ED is consumed, or when a low or moderate ED dose is consumed.

#### What were the interactive effects of alcohol and ED dose on subjective intoxication? Were there interactive effects of alcohol and ED after controlling for differences in BAC?

Ratings of subjective intoxication did not differ significantly between the alcohol groups according to the amount of ED consumed ( $p=.816$ ).

However, the aforementioned dose-dependent effects of ED on subjective intoxication may be indeed be accurate estimations as there were significant effects of ED dose on BAC. To test this, differences in BAC were statistically controlled: when this was done *there were no significant differences in ratings of subjective intoxication according to ED dose at either the moderate or high alcohol doses* ( $p=.651$  and  $p=.759$ ). *These results suggest that having ED does not change the estimation of intoxication after consuming alcohol.*

## Subjective Intoxication Ratings

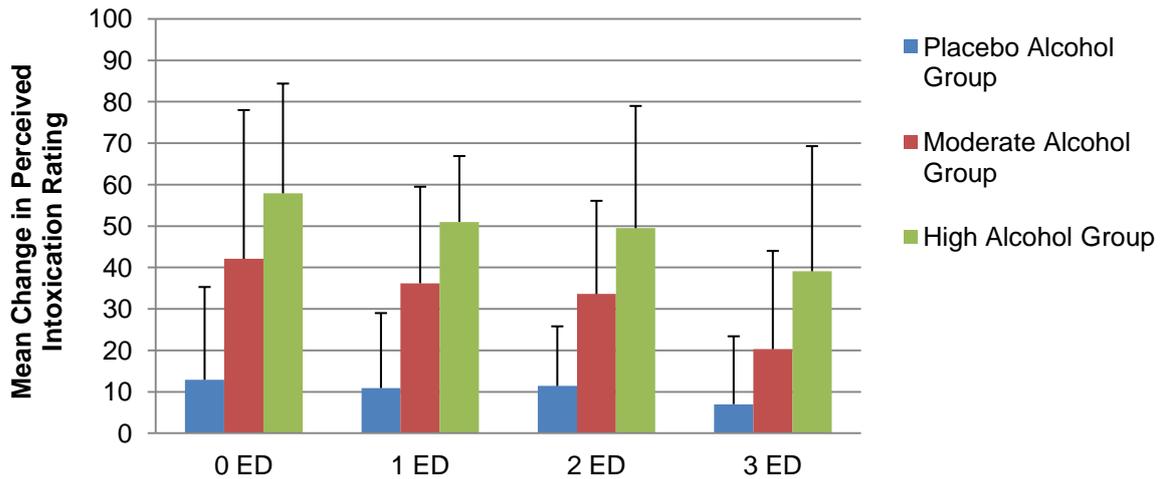


Figure 62. Mean change in rating of intoxication (0-100) from baseline to 30 minutes after commencing beverage consumption for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation)

### Were there sex differences in the effects of alcohol and ED dose on subjective intoxication ratings?

There were no significant differences between males and females in the effect of alcohol and ED dose on the change in subjective intoxication ratings ( $p > .467$ ).

### Beverage Rating Scale: Perceived Alcohol Intake

Figure 63 displays the number of bottles of beer (4.8%; 1.4 standard drinks) participants thought they were administered according to alcohol group and number of EDs co-ingested.

### Manipulation check: did estimation of alcohol consumed increase with an increasing alcohol dose?

There was a statistically significant effect of alcohol dose on perceived alcohol intake,  $F(2, 26) = 4.776$ ,  $p = .017$ . Follow-up tests revealed that the high alcohol group ( $M = 2.0$ ,  $SD = 0.5$ ) reported significantly greater alcohol intake relative to the moderate ( $M = 1.3$ ,  $SD = 0.6$ ;  $p = .014$ ,  $g = 1.27$ ) and the placebo ( $M = 1.2$ ,  $SD = 0.6$ ;  $p = .006$ ,  $g = 1.40$ ) alcohol groups. These results suggest that participants were poor at discriminating between moderate alcohol and placebo alcohol doses, as estimation of alcohol consumed did not differ significantly between these groups.

### What were the dose dependent effects of ED on estimation of alcohol consumed?

There were no significant dose-dependent effects of ED intake on perceived alcohol intake ( $p=.266$ ).

### What were the interactive effects of alcohol and ED dose on estimation of alcohol consumed?

#### Were there interactive effects of alcohol and ED after controlling for differences in BAC?

The alcohol groups did not differ in estimation of alcohol intake according to the amount of ED consumed ( $p=.845$ ). Furthermore, estimation of alcohol consumed was not affected by ED dose for either the moderate ( $p=.703$ ) or high ( $p=.638$ ) alcohol conditions when the existing differences in BAC across the ED doses were statistically controlled.

### Were there sex differences in the effects of alcohol and ED dose on estimation of alcohol consumed?

There was no significant difference between males and females in their estimation of alcohol intake, regardless of the alcohol and/or ED dose consumed ( $p<.232$ ).

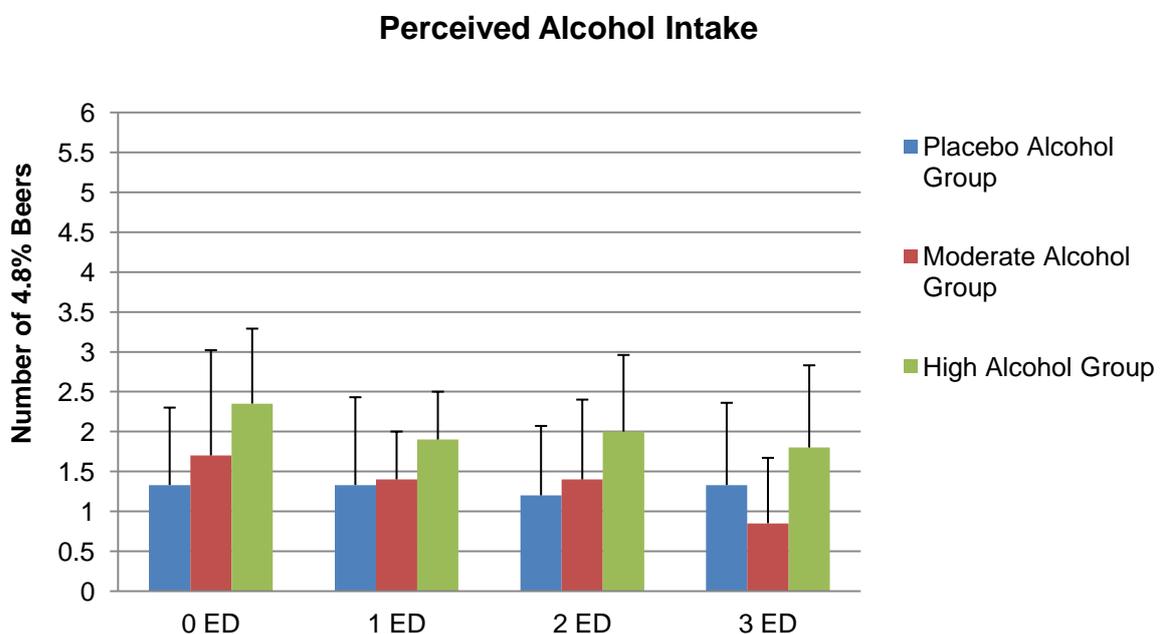


Figure 63. Mean perceived intake of alcoholic drinks (375mL 4.8% beers or 1.4 standard drinks) reported by alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation)

### Beverage Rating Scale: Perceived ED Intake

Figure 64 displays the perceived number of standard 250mL EDs participants thought they were administered according to alcohol group and number of EDs actually co-ingested.

### **Manipulation check: did estimation of standard ED intake increase with an increasing ED dose?**

There was a statistically significant effect of ED dose on perceived ED intake,  $F(3, 78)=6.034$ ,  $p=.001$ . Participants reported significantly higher ED intake when they had consumed two standard EDs ( $M=1.5$ ,  $SD=1.0$ ) compared to when they had consumed no EDs ( $M=0.8$ ,  $SD=0.8$ ,  $p=.002$ ,  $g=0.82$ ), one standard ED ( $M=0.8$ ,  $SD=0.6$ ,  $p=.005$ ,  $g=0.87$ ) and three standard EDs ( $M=1.0$ ,  $SD=0.6$ ,  $p=.026$ ,  $g=0.61$ ), regardless of whether alcohol was consumed or not. These results suggest that participants were good at judging their ED intake up until the recommended maximum daily intake (i.e., two standard EDs), with an underestimation of ED intake occurring when consuming in excess of these guidelines (i.e., three standard EDs). Furthermore, it can be argued that the placebo ED manipulation was successful, as participants reported ED intake in the placebo ED condition.

### **What are the dose dependent effects of alcohol intake on estimation of ED consumed?**

Participants' perceived ED intake also differed according to alcohol group,  $F(2, 26)=4.776$ ,  $p=.017$ . Follow-up analyses revealed that ED intake reported by the high alcohol group ( $M=2.0$ ,  $SD=0.5$ ) was significantly higher than that reported by the moderate ( $M=1.3$ ,  $SD=0.6$ ,  $p=.014$ ,  $g=1.22$ ) and placebo ( $M=1.2$ ,  $SD=0.6$ ,  $p=.006$ ,  $g=1.40$ ) alcohol groups, regardless of actual ED intake. As the placebo, moderate, and high alcohol groups received the same amount of ED across the sessions, these results suggest that a higher alcohol dose results in greater perceived ED intake relative to a moderate or placebo alcohol dose.

### **What were the interactive effects of alcohol and ED dose on estimation of ED consumed?**

#### **Were there interactive effects of alcohol and ED after controlling for differences in BAC?**

There was no significant difference between the alcohol groups in estimation of ED intake according to the amount of ED consumed ( $p=.553$ ).

We statistically controlled for changes in BAC according to the ED dose consumed for the moderate and high alcohol group. After controlling for BAC differences, the moderate alcohol group were not able to discern any difference in perceived ED intake between no ED, one, two or three standard EDs ( $p=.219$ ). In contrast, there was a statistically significant difference in perceived ED intake for the high alcohol group according to the amount of ED co-ingested,  $F(3, 40)=4.623$ ,  $p=.008$ . Participants who received the high alcohol dose reported greater ED intake when they had consumed two standard EDs ( $M=1.5$ ,  $SD=1.0$ ) relative to when they had consumed no EDs ( $M=0.7$ ,  $SD=1.0$ ,  $p=.007$ ,  $g=0.80$ ) and when they had consumed one standard ED ( $M=0.8$ ,  $SD=1.0$ ,  $p=.041$ ,  $g=0.70$ ). There was no significant difference in estimation of ED intake after consuming three EDs ( $M=1.0$ ,  $SD=1.0$ ) relative to two standard EDs, one standard EDs and no ED consumption ( $ps>.196$ ).

These results suggest that participants were not able to differentiate between placebo, one, two or three standard EDs when they consumed a moderate alcohol dose. However, when they had a high alcohol dose, they could differentiate a moderate ED dose (i.e., two standard EDs) from a low ED

dose (i.e., one standard ED) or no ED consumption, but they could not distinguish between consuming a high ED dose (i.e., three standard EDs) and low or no ED consumption.

### Were there sex differences in the effects of alcohol and ED dose on estimation of ED consumed?

There was no significant difference between males and females in their perceived estimation of ED intake, regardless of the alcohol and/or ED dose consumed ( $p>.275$ ).

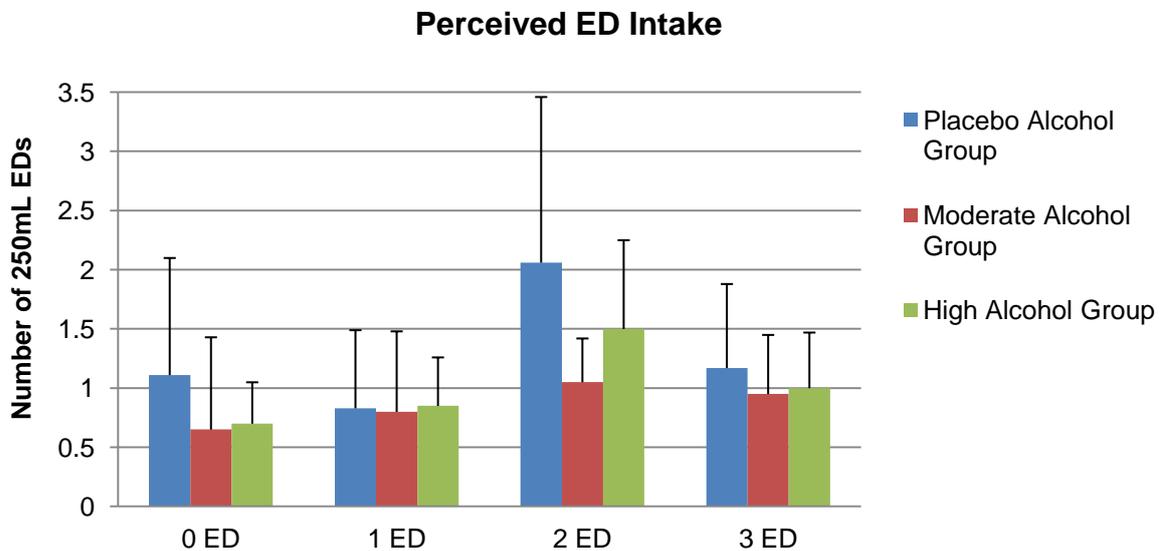


Figure 64. Mean perceived intake of standard 250mL EDs reported by each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation)

### Summary of Perceived Intoxication Outcomes

Consumption of a high ED dose appeared to lower perception of intoxication relative to when no ED was consumed, or when a low or moderate ED dose was consumed, regardless of the amount of alcohol consumed. However, this outcome may have reflected an accurate estimation of intoxication by participants, as BAC was typically lower after consumption of a higher ED dose relative to no ED consumption. This conclusion was supported by the finding that ratings of intoxication and ratings of perceived alcohol intake did not differ according to the amount of ED consumed after controlling for differences in BAC for the moderate and high alcohol groups, suggesting that ratings of intoxication are not altered when a moderate or high alcohol dose is ingested with EDs relative to when it is ingested without EDs.

In regards to estimation of ED intake, participants were good at judging their ED intake up until the recommended daily intake threshold (i.e., maximum of two standard EDs per day); participants tended to underestimate their ED intake when consuming in excess of these guidelines (i.e., three standard EDs). However, when we controlled for differences in BAC across the ED conditions for the moderate and high alcohol groups, we found that this result was not as clear-cut. Participants could not differentiate between the different ED doses when they had consumed a moderate alcohol dose.

While they could detect the difference between a moderate ED dose and a low ED or no ED dose after a high alcohol dose, they could not tell the difference between a high ED dose compared to moderate, low, or no ED consumption. These results suggest that alcohol consumption may impact on the ability to accurately detect the amount of ED consumed, with participants particularly poor at detecting a high ED dose which exceed the recommended daily intake guidelines.

#### **5.4.4 Objective Intoxication Outcomes**

##### **Occupational Safety Performance Assessment Technology (OSPAT)**

The OSPAT is a psychomotor measure of tracking performance which requires eye-hand coordination and focused attention, with higher scores indicating better tracking performance. The OSPAT scores for each alcohol group are displayed in Figure 65 according to number of EDs co-ingested.

Analyses were conducted to confirm that the OSPAT was sensitive to the effects of active alcohol relative to placebo alcohol. There was a small (but not statistically significant) magnitude decrease in OSPAT performance after consuming the high alcohol dose with no ED ( $M=13.9$ ,  $SD=1.5$ ) compared to the placebo alcohol dose with no ED ( $M=14.1$ ,  $SD=0.8$ ,  $p=.670$ ,  $g=0.19$ ), showing that performance on the test was negatively affected by alcohol, albeit of small magnitude.

However, analyses revealed no statistically significant dose-dependent effect of alcohol when OSPAT performance was averaged across the ED conditions ( $p=.487$ ). Furthermore, there were no significant dose-dependent effects on ED on OSPAT scores ( $p=.108$ ). Most importantly, OSPAT scores did not differ between the alcohol groups according to the amount of ED consumed ( $p=.871$ ). These results suggest that there was no dose-dependent effect of alcohol, or ED, or interactive effect of consuming alcohol with ED, on tracking performance. We conducted further analyses statistically controlling for differences in BAC across the ED doses, to see if OSPAT performance differed according to the amount of ED consumed when differences in BAC were ruled out. However, the results supported our conclusions, in that there was no difference in OSPAT scores according to the ED dose co-ingested for the moderate alcohol group ( $p=.993$ ) or the high alcohol group ( $p=.757$ ). Further analyses also confirmed that OSPAT performance did not differ between males and females according to the amount of alcohol and/or ED consumed ( $ps>.211$ ).

When considering these results, it is important to note that the standard deviations (depicted by the error bars in Figure 65) show a high variability in scores when the same alcohol dose was consumed with the same amount of ED. Such variability in scores means that there was reduced statistical power to detect a consistent difference when comparing performance under different alcohol and ED doses with the current sample size.

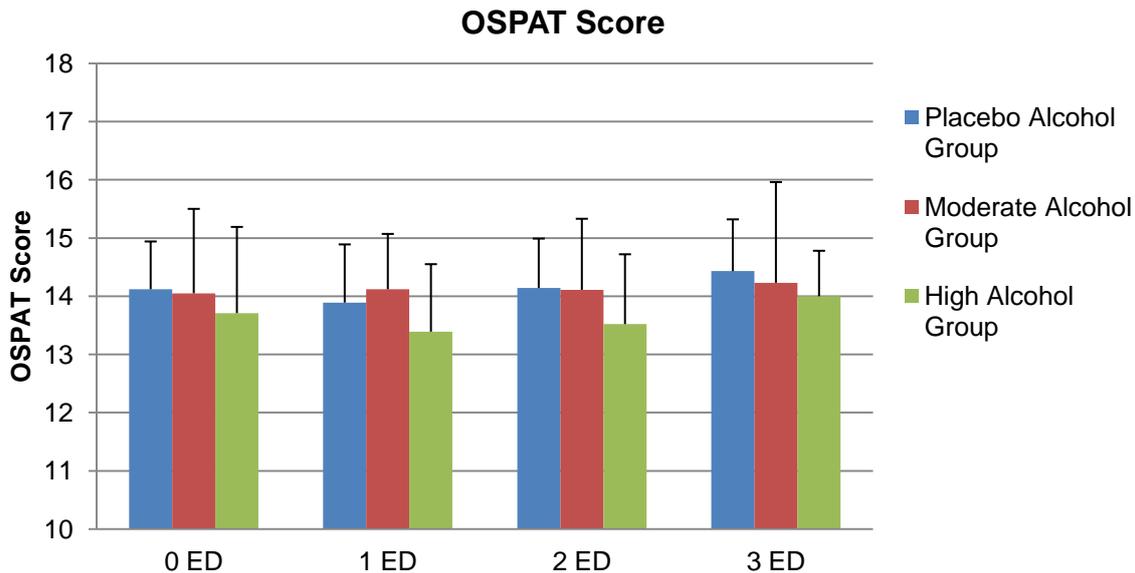


Figure 65. Mean OSPAT score for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation)

#### CANTAB Reaction Time Index (RTI): Simple RT

Simple RT for each alcohol group is displayed in Figure 66 according to the number of EDs co-ingested; a faster RT (smaller number) demonstrates better sensory-motor speeded performance.

Analyses were conducted to confirm that the simple RT index was sensitive to the effects of active alcohol relative to placebo alcohol. There was a moderate (but not statistically significant) magnitude increase in simple RT after consuming the high alcohol dose ( $M=282.5$ ,  $SD=26.3$ ) with no EDs compared to the placebo alcohol dose with no EDs ( $M=271.6$ ,  $SD=23.6$ ,  $p=.343$ ,  $g=0.44$ ), showing that the measure was sensitive to alcohol-induced impairment of simple RT.

There was no statistically significant alcohol dose-dependent differences in simple RT when performance was averaged across the ED conditions ( $p=.487$ ), nor were there any significant dose-dependent effects of ED on simple RT ( $p=.108$ ). There was also no significant interactive effect of alcohol and ED dose on simple RT ( $p=.871$ ), suggesting that simple RT did not differ between the alcohol groups according to the amount of ED consumed. Even after controlling for differences in BAC across the ED conditions, there was no difference in simple RT according to the amount of ED consumed for the moderate alcohol group ( $p=.559$ ) or high alcohol group ( $p=.815$ ).

Further analyses checking for sex differences in performance showed that there was no significant difference in simple RT for males and females according to the amount of alcohol and ED consumed ( $ps>.256$ ).

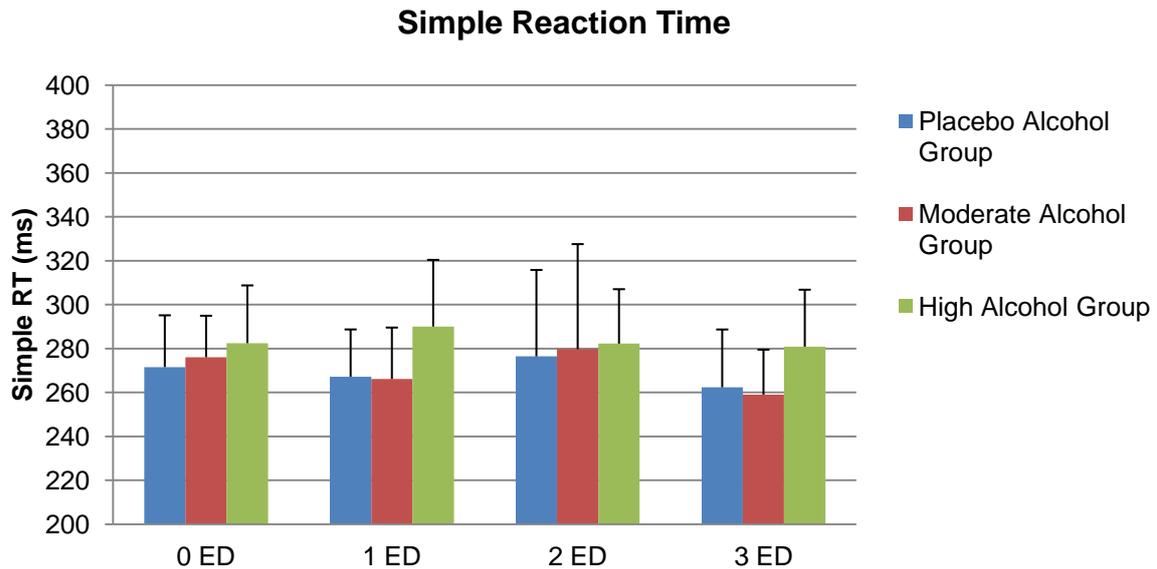


Figure 66. Mean simple reaction time for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation)

#### CANTAB Reaction Time Index (RTI): Choice RT

Choice RT for each alcohol group is displayed in Figure 67 according to the number of EDs co-ingested; a faster RT (smaller number) demonstrates better sensory-motor speeded performance.

There was a small (but not statistically significant) magnitude increase in choice RT after consuming the high alcohol dose with no EDs ( $M=300.8$ ,  $SD=30.1$ ) compared to the placebo alcohol dose with no EDs ( $M=296.4$ ,  $SD=27.6$ ,  $p=.735$ ,  $g=0.15$ ), showing that there were effects of alcohol on this task. However, it should be emphasised that this effect was small, suggesting that there was reduced power to reliably detect alcohol effects, and hence AED effects, for this task.

Similar to simple RT, there was no statistically significant dose-dependent effect of alcohol on choice RT when performance was averaged across the ED conditions ( $p=.676$ ), nor were there any dose-dependent effects of ED on choice RT ( $p=.194$ ). Choice RT did not differ between the alcohol groups according to the amount of ED consumed, as the interactive effect of alcohol and ED was not statistically significant ( $p=.759$ ). Even after controlling for differences in BAC across the ED doses, there was no difference in choice RT according to the amount of ED consumed for the moderate alcohol group ( $p=.103$ ) or high alcohol group ( $p=.984$ ). Furthermore, there was no significant difference between male and female participants in their choice RT according to the amount of alcohol and ED consumed ( $ps>.182$ ).

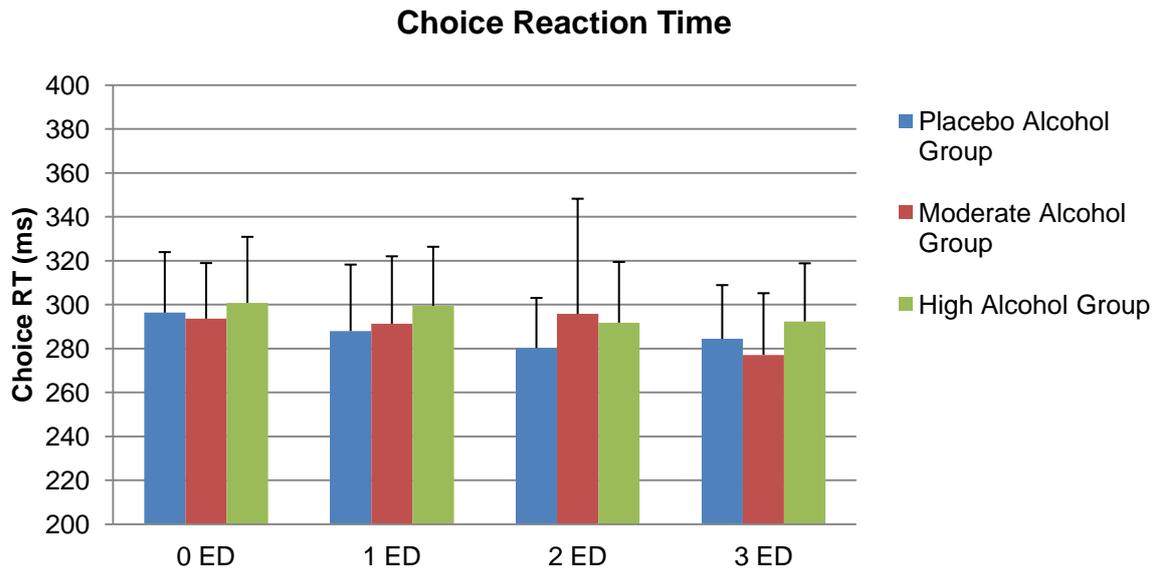


Figure 67. Mean choice reaction time for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation)

#### CANTAB Rapid Visual Processing (RVP): Mean RVP Latency

Mean RVP latency for each alcohol group is displayed in Figure 68 according to the number of EDs co-ingested; a faster latency (smaller number) indicates better sustained attention over the length of the task.

There was a statistically significant large magnitude increase in RVP latency after consuming the high alcohol dose with no EDs ( $M=387.9$ ,  $SD=61.0$ ) compared to the placebo alcohol dose with no EDs ( $M=332.6$ ,  $SD=34.9$ ,  $p=.026$   $g=1.11$ ), showing that the measure was sensitive to alcohol-induced impairment of RVP latency and had sufficient power to detect AED effects.

There was no statistically significant dose-dependent effect of alcohol on mean RVP latency when performance was averaged across the ED conditions ( $p=.130$ ) nor were there any significant dose-dependent effects of ED ( $p=.289$ ). There was no significant difference between the alcohol groups in mean RVP latency according to the amount of ED consumed ( $p=.699$ ). This absence of an interactive effect was supported by analyses controlling for differences in BAC across the ED doses, with no significant difference in mean RVP latency according to the ED dose co-ingested for the moderate alcohol group ( $p=.696$ ) or the high alcohol group ( $p=.821$ ). Furthermore, there was no difference between male and female participants in their RVP latency according to the alcohol and ED dose consumed ( $p>.177$ ).

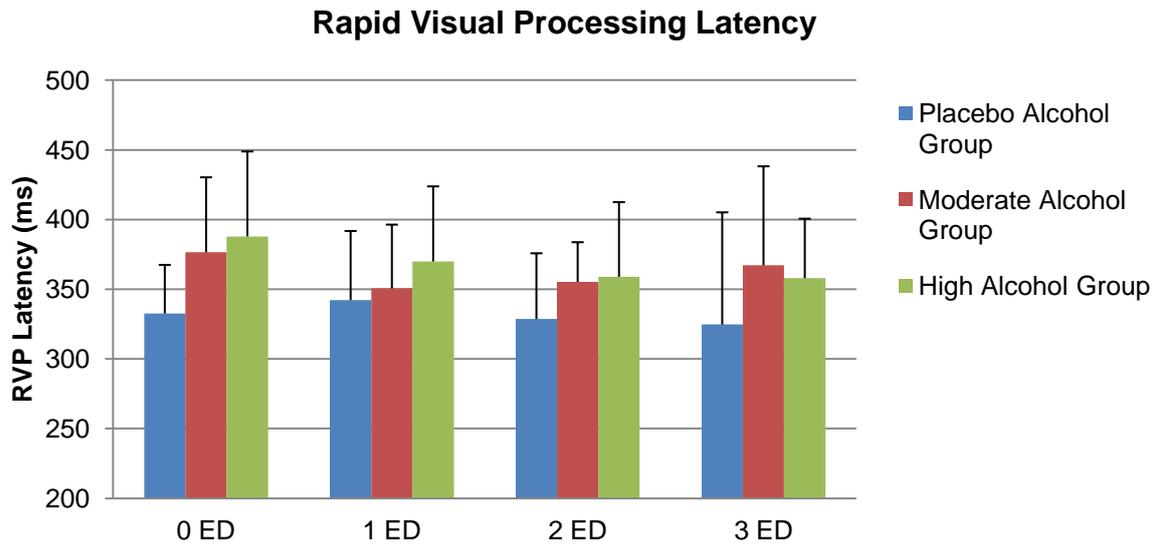


Figure 68. Mean Rapid Visual Processing Latency for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation)

#### CANTAB Stop-Signal Task (SST): Stop-Signal Reaction Time (SSRT)

The mean length of time between the go and stop stimulus at which the participant was able to inhibit their response on 50% of the trials, otherwise known as the stop signal reaction time (SSRT), was calculated for this task. Mean SSRT is displayed in Figure 69 for each alcohol group according to the number of EDs co-ingested; a faster time (smaller number) indicates better response inhibition and less impulsivity.

There was a small (but not statistically significant) magnitude increase in SSRT after consuming the high alcohol dose with no EDs ( $M=154.7$ ,  $SD=38.3$ ) compared to the placebo alcohol dose with no EDs ( $M=151.0$ ,  $SD=26.6$ ,  $p=.802$ ,  $g=0.11$ ), showing that there were effects of alcohol on the task. However, it should be emphasised that this effect was small, suggesting that there was reduced power to reliably detect alcohol effects, and hence AED effects, for this task.

There was no significant dose-dependent effect of alcohol on SSRT ( $p=.318$ ) when performance was averaged across the ED conditions, nor were there any significant dose-dependent effects of ED on SSRT ( $p=.303$ ). There was no significant interactive effect of alcohol and ED ( $p=.873$ ), suggesting that the ability to inhibit responses did not differ between the alcohol groups according to the amount of ED consumed. This conclusion was supported by analyses controlling for existing differences in BAC due to the amount of ED consumed. These analyses showed no significant difference in SSRT according to the ED dose co-ingested for the moderate alcohol group ( $p=.696$ ) and the high alcohol group ( $p=.607$ ) after controlling for differences in BAC. Furthermore, there was no significant difference between males and females in their performance according to the amount of alcohol and ED consumed ( $ps>.430$ ).

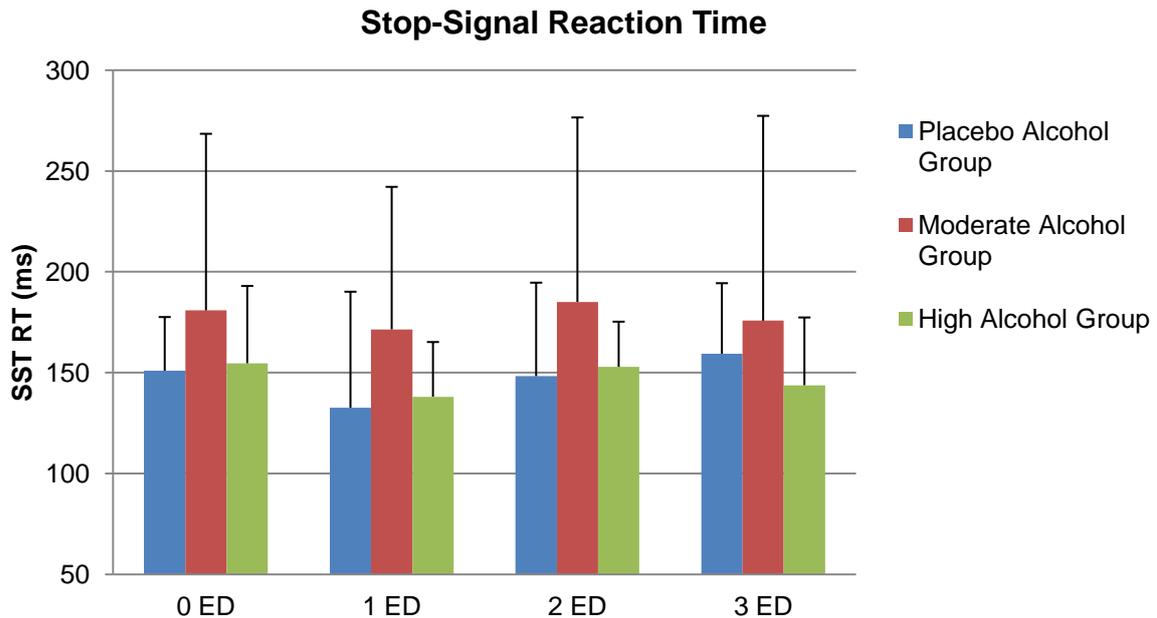


Figure 69. Mean stop-signal task reaction time for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation)

### Purdue Pegboard Task: Gross Motor Movement

Figure 70 displays the mean number of pegs placed in the pegboard with the dominant hand by each alcohol group; a higher number of pegs indicates better gross motor movement.

There was a moderate magnitude (but non-significant) decrease in the number of pegs placed in the pegboard with the dominant hand after consuming the high alcohol dose with no EDs ( $M=15.6$ ,  $SD=1.7$ ) compared to the placebo alcohol dose with no EDs ( $M=16.3$ ,  $SD=2.0$ ,  $p=.397$ ,  $g=0.39$ ), showing that the measure was sensitive to alcohol-induced impairment of gross motor movement.

There was no significant dose-dependent effect of alcohol on gross motor movement when performance was averaged across the ED conditions ( $p=.792$ ). There was a trend towards a significant dose-dependent effect of ED on dominant hand performance,  $F(3, 81)=2.335$ ,  $p=.080$ . Specifically, participants placed more pegs with the dominant hand when they had consumed one standard ED ( $M=16.8$ ,  $SD=1.7$ ) compared to when they had consumed two standard EDs ( $M=16.3$ ,  $SD=1.8$ ,  $p=.074$ ,  $g=0.29$ ) or three standard EDs ( $M=15.9$ ,  $SD=1.7$ ,  $p=.003$ ,  $g=0.53$ ), regardless of whether they had consumed alcohol or not. These results suggest that participants had better gross motor movement when they consumed a low ED dose compared to a moderate or high ED dose.

However, there was no significant interactive effect of alcohol and ED on performance ( $p=.471$ ), suggesting that gross motor movement did not differ between the alcohol group according to the amount of ED consumed. Even when differences in BAC across the ED doses were statistically controlled, there was no dose-dependent difference in gross motor movement for the moderate

alcohol group ( $p=.381$ ) or the high alcohol group ( $p=.207$ ), suggesting that the aforementioned ED-induced differences in gross motor movement may have reflected actual differences in BAC.

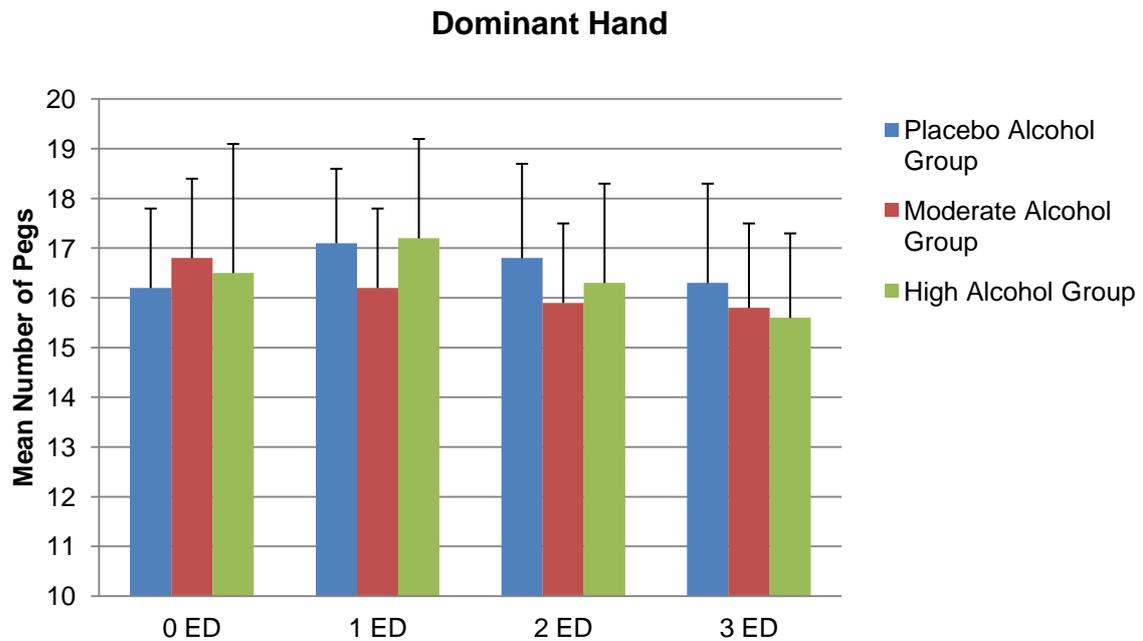
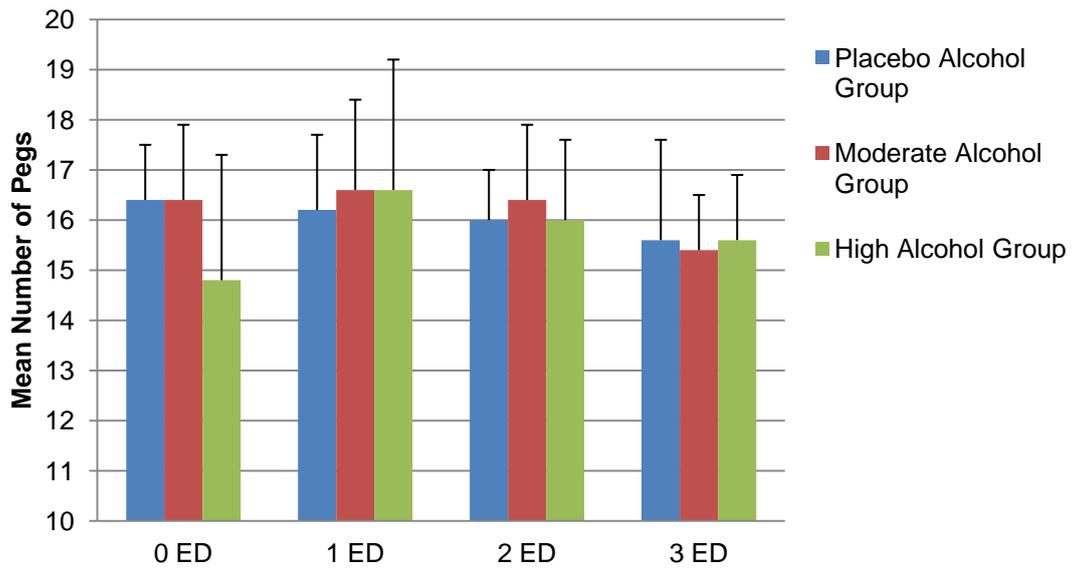


Figure 70. Mean number of pegs placed with the dominant hand by each alcohol group according to the number of EDs co-ingested

Comparison of gross motor performance by males and females revealed significant sex differences according to the dose of alcohol and ED consumed,  $F(6, 72)=2.737$ ,  $p=.019$  (see Figure 71). Follow-up analyses showed that males did not differ in their gross motor performance according to the amount of alcohol and ED consumed ( $ps>.312$ ). In contrast, female participants' gross motor performance was significantly impacted by the dose of alcohol and ED,  $F(3, 21)=3.384$ ,  $p=.009$ .

In the placebo alcohol group, females tended to perform better when they had one standard ED ( $M=18.0$ ,  $SD=1.0$ ) compared to no ED ( $M=16.0$ ,  $SD=2.0$ ,  $p=.075$ ,  $g=1.27$ ). In the moderate alcohol group, females tended to perform better when they had no ED ( $M=17.2$ ,  $SD=1.8$ ) compared to when they had one ( $M=15.8$ ,  $SD=1.5$ ,  $p=.005$ ,  $g=0.85$ ), two ( $M=15.4$ ,  $SD=1.7$ ,  $p=.088$ ,  $g=1.03$ ), or three ( $M=16.2$ ,  $SD=2.2$ ,  $p=.034$ ,  $g=0.50$ ) standard EDs. In the high alcohol group, females tended to perform better when they had no ED ( $M=18.2$ ,  $SD=1.5$ ,  $p=.003$ ,  $g=1.43$ ) or one standard ED ( $M=17.8$ ,  $SD=1.3$ ,  $p=.051$ ,  $g=1.26$ ) compared to when they had three standard EDs ( $M=15.6$ ,  $SD=2.1$ ). They also performed better when they had no ED compared to when they ingested two standard EDs with the high alcohol dose ( $M=16.6$ ,  $SD=2.5$ ,  $p=.078$ ,  $g=0.78$ ). These results suggest differential effects of alcohol and ED on gross motor performance for female consumers.

### Dominant Hand: Males



### Dominant Hand: Females

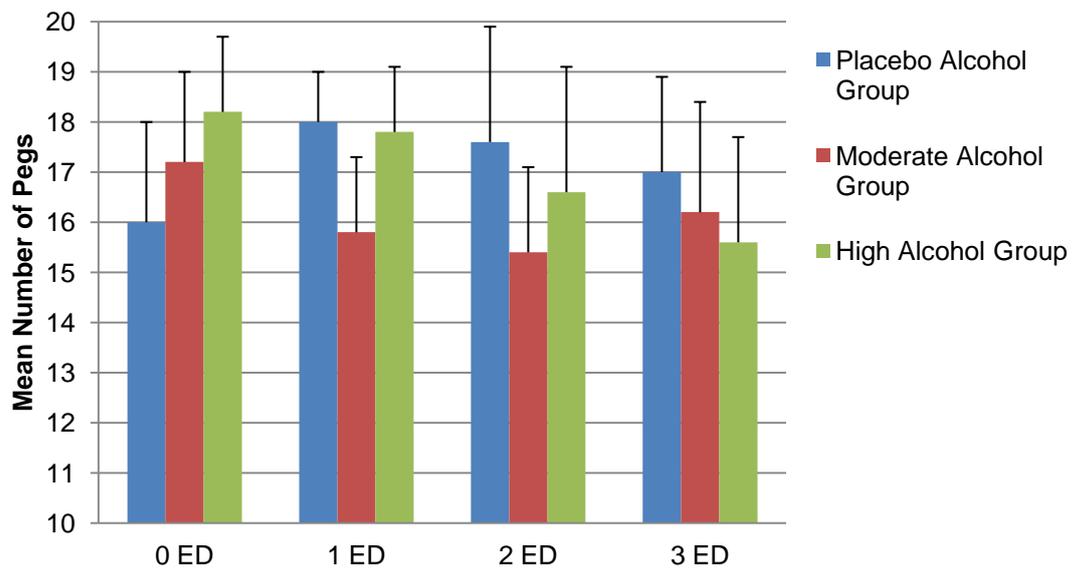


Figure 71. Mean number of pegs placed with the dominant hand by males (upper panel) and females (lower panels) in each alcohol group according to the number of energy drinks (EDs) co-ingested

### Purdue Pegboard Task: Fine Motor Movement

Figure 72 shows the mean number of parts assembled by each alcohol group according to the number of EDs co-ingested; a higher number of assembled parts indicates better fine motor movement.

There was a moderate magnitude (but non-significant) decrease in the number of parts assembled after consuming the high alcohol dose with no EDs ( $M=34.9$ ,  $SD=4.9$ ) compared to the placebo alcohol dose with no EDs ( $M=38.4$ ,  $SD=5.4$ ,  $p=.148$ ,  $g=0.68$ ), showing that the measure was sensitive to alcohol-induced impairment of fine motor movement.

There was no statistically significant dose-dependent effect of alcohol on the number of parts assembled when performance was averaged across the ED conditions ( $p=.986$ ), nor were there any significant dose-dependent effects of ED on this measure of fine motor movement ( $p=.339$ ). The number of parts assembled did not differ significantly between the alcohol groups according to the amount of ED consumed ( $p=.430$ ). Even after controlling for differences in BAC across the ED conditions, there was no significant ED dose-dependent differences in fine motor movement for the moderate alcohol group ( $p=.415$ ) or the high alcohol group ( $p=.489$ ).

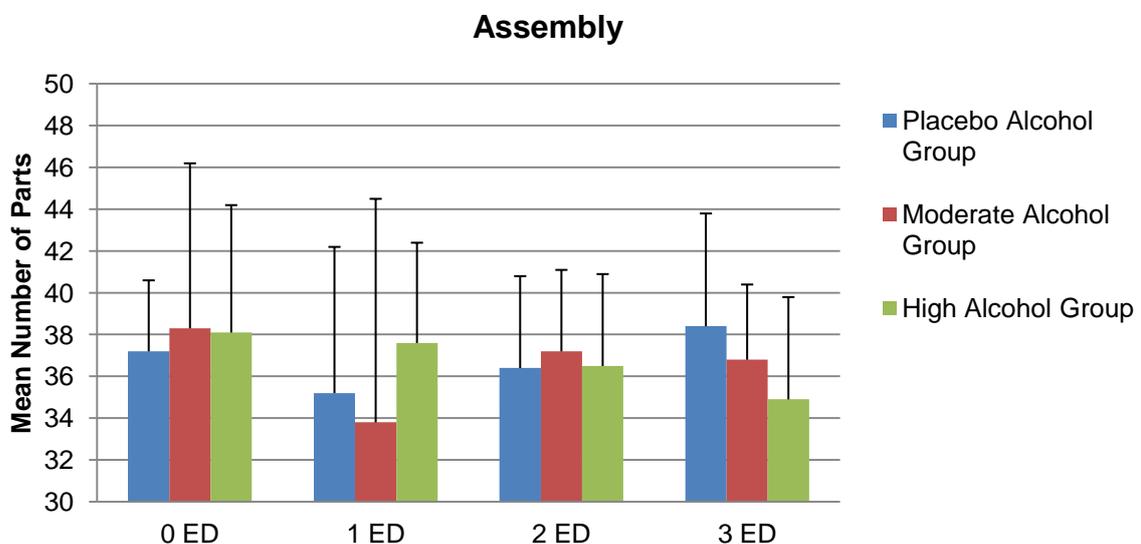


Figure 72. Mean number of pegs completed during the assembly trial by each alcohol group according to the number of EDs co-ingested

There was a significant difference between males and females in fine motor movement according to whether they were in the placebo, moderate, or high alcohol group,  $F(2, 24)=4.545$ ,  $p=.021$ . In the placebo alcohol group, females ( $M=39.3$ ,  $SD=3.5$ ) tended to have significantly better fine motor movement than males ( $M=34.4$ ,  $SD=3.7$ ,  $p=.062$ ,  $g=1.36$ ). There was no significant sex differences in fine motor movement for the moderate ( $p=.132$ ) and the high ( $p=.175$ ) alcohol groups. These results suggest that sex differences in fine motor movement may be reduced or disappear following consumption of a moderate or high alcohol dose.

## Balance

Figure 73 displays the mean sway area (95% ellipse sway area; cm<sup>2</sup>) when standing with eyes open for each alcohol group according to the number of EDs co-ingested; greater sway area (larger numbers) corresponds to greater balance instability.

There was a moderate magnitude (but non-significant) increase in mean sway area after consuming the high alcohol dose with no EDs ( $M=3.62$ ,  $SD=1.70$ ) compared to the placebo alcohol dose with no EDs ( $M=2.81$ ,  $SD=1.09$ ,  $p=.217$ ,  $g=0.57$ ), showing that the measure was sensitive to alcohol-induced impairment of balance.

There was no significant dose-dependent effect of alcohol on mean sway area when performance was averaged across the ED conditions ( $p=.185$ ) nor were there any significant dose-dependent effects of ED ( $p=.557$ ). Balance performance did not differ between the alcohol groups according to the amount of ED consumed, as evidenced by a non-significant interaction between alcohol group and ED dose ( $p=.815$ ).

Analyses were conducted to see if there were any ED dose-dependent differences in balance performance for the moderate and high alcohol group when differences in BAC across the ED doses were statistically controlled. These analyses showed that there was a trend towards significant differences in mean sway area according to ED dose for the moderate alcohol group ( $p=.088$ ). Follow-up analyses revealed a trend towards a smaller sway area (i.e., *better balance*) when the moderate alcohol dose was consumed with three standard EDs ( $M=1.92$ ,  $SD=2.55$ ) compared to when the same alcohol dose was consumed without EDs ( $M=3.61$ ,  $SD=2.63$ ,  $p=.079$ ,  $g=0.65$ ). There was no significant difference in balance performance for the high alcohol group when differences in BAC were statistically controlled ( $p=.818$ ). Thus, it appears that consuming alcohol with an ED dose in-excess of the recommended maximum daily intake (i.e., three standard EDs) may improve balance relative to consuming the same dose of alcohol alone. It should be emphasised that this effect was only evident when consuming the moderate alcohol dose; there was no difference in balance when a high alcohol dose was consumed with or without EDs.

Analyses looking to see if there were sex differences in balance outcomes showed that there was no significant difference between males and females in the effect of alcohol and ED on mean sway area ( $ps>.638$ ).

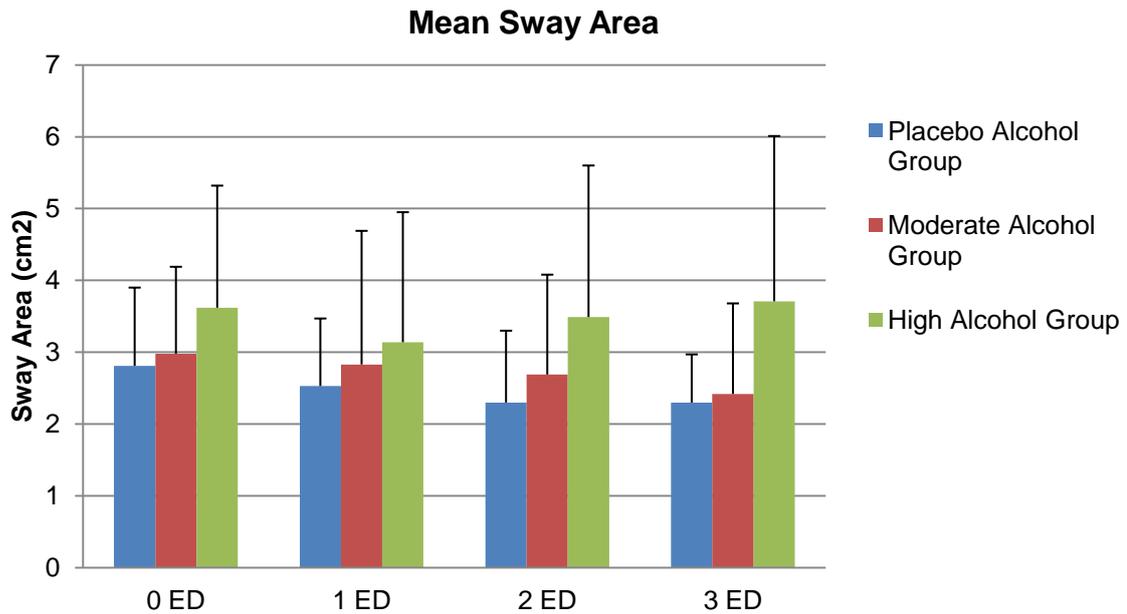


Figure 73. Mean sway area (cm<sup>2</sup>) for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation)

### Driving Performance

Driving performance on the driving simulator task was assessed as a more ecologically valid measure of cognitive and motor performance. The percentage of time out of lane was used as an indicator of driving performance, with a higher percentage indicative of poorer performance. Figure 74 displays the mean time out of lane (%) for each alcohol group according to the number of EDs co-ingested.

There was a small (but not statistically significant) magnitude increase in time out of lane after consuming the high alcohol dose with no EDs ( $M=9.0$ ,  $SD=8.7$ ) compared to the placebo alcohol dose with no EDs ( $M=5.7$ ,  $SD=9.2$ ,  $p=.425$ ,  $g=0.37$ ), showing that there were effects of alcohol on the task. However, it should be emphasised that this effect was small, suggesting that there was reduced power to reliably detect alcohol effects, and hence AED effects, for this task.

There was no significant dose-dependent effect of alcohol on driving performance when performance was averaged across the ED conditions ( $p=.415$ ), nor were there any significant dose-dependent effects of ED ( $p=.151$ ). Furthermore, driving performance did not differ between the alcohol groups according to the amount of ED consumed, as indicated by a non-significant interactive effect of alcohol and ED ( $p=.508$ ). This conclusion was supported by subsequent analyses controlling for differences in BAC across the ED doses for the moderate and high alcohol group. These analyses revealed no significant ED dose-dependent effects for the moderate alcohol group ( $p=.899$ ) or the high alcohol group ( $p=.946$ ) on driving performance after controlling for BAC. Furthermore, there was no difference between males and females in their driving performance according to the amount of alcohol and ED consumed ( $ps>.507$ ).

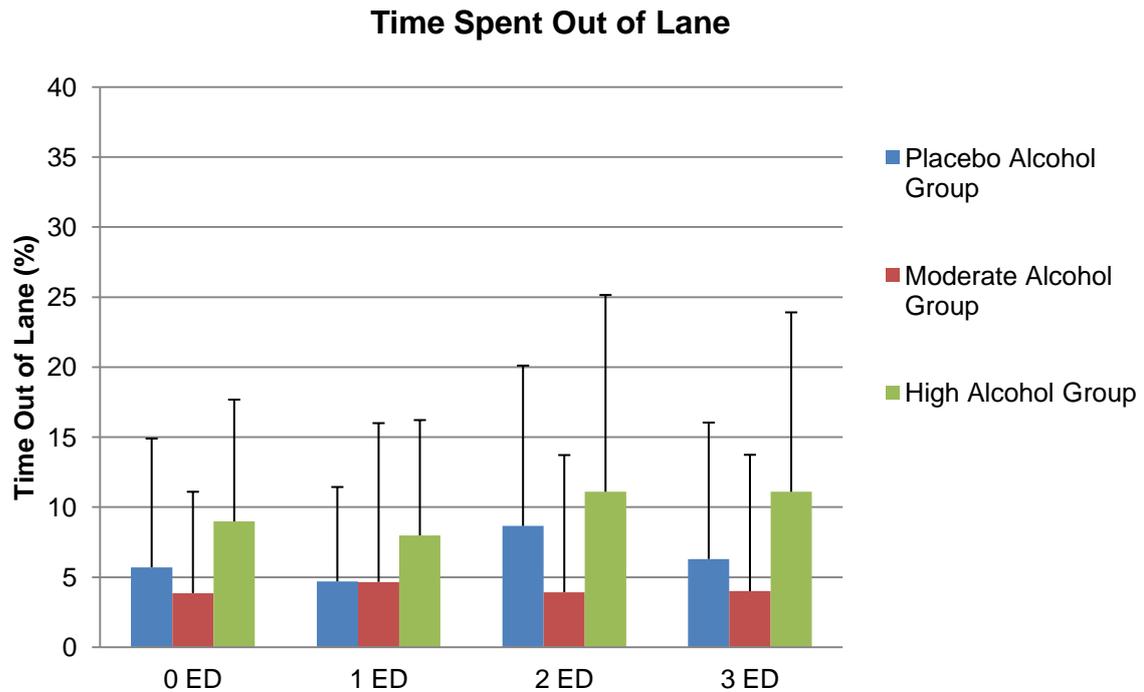


Figure 74. Mean time out of lane (%) for each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation)

### Summary of Objective Intoxication Outcomes

Initial analyses showed that there was typically moderate magnitude impairment in motor performance after consuming the high active alcohol dose compared to placebo alcohol without ED, suggesting that the tasks detected the effects of alcohol and thus were sensitive to any potential AED effects. However, half the cognitive measures (choice RT, SSRT and driving performance) only showed small magnitude impairment after consuming the high alcohol dose without ED relative to the placebo dose without ED and only one measure (RVP) detected a large magnitude significant impairment of performance after consuming the high alcohol dose. While these results suggest the tasks were sensitive to the effects of alcohol, they typically only identified small magnitude, and statistically non-significant effects and thus there was limited experimental power to identify potential alcohol and AED effects unless they were very substantial.

*What were the dose-dependent effects of alcohol on cognitive and motor intoxication outcomes (regardless of ED intake)?*

In light of the above discussion, it was not surprising that there were no statistically significant dose-dependent effects of alcohol on measures of cognitive performance when performance for each alcohol group was averaged across the ED conditions. Furthermore, there was no significant impact of consuming alcohol (when performance was averaged across the ED conditions) on gross and fine motor movement or balance or on driving performance.

*What were the dose-dependent effects of ED on cognitive and motor intoxication outcomes (regardless of alcohol intake)?*

There were no improving or impairing effects of ED on the tasks administered in the present study assessing cognitive performance or driving performance. While ED dose did not impact on fine motor movement and balance, there were dose-dependent effects of ED on gross motor movement, whereby participants had better gross motor movement when they consumed the low ED dose (i.e., one standard ED) compared to the moderate or high ED dose. However, it should be noted that these effects may reflect actual differences in BAC between the ED conditions.

*What were the interactive effects of alcohol and ED dose on cognitive and motor intoxication outcomes? Were these interactive effects of alcohol and ED present after controlling for differences in BAC?*

There were no interactive effects of consuming alcohol with EDs on the OSPAT and the CANTAB RTI, RVP, and SST, even after controlling for differences in BAC across the ED doses for the active alcohol groups. It should be noted that there were also no difference in driving performance between the alcohol groups according to the amount of ED consumed. These results suggest that cognitive performance, as assessed using the measures in the present study, does not differ after consuming AED versus alcohol. However, these results need to be interpreted with caution in light of the low statistical power (with the current sample size) to reliably detect the effects of alcohol and AED on performance outcomes, and the selective range of cognitive measures administered.

There was no significant difference in motor performance between the alcohol groups according to the ED dose consumed. However, when BAC differences across the ED doses were statistically controlled, it appeared that consuming alcohol with an ED dose in excess of the recommended maximum daily intake (i.e., three standard EDs) improved balance compared to consuming the same dose of alcohol alone. However, this effect was only evident when consuming the moderate alcohol dose, suggesting that ED intake (and the volume) may not have beneficial effects on balance when a high alcohol dose is consumed. There were still no differences in fine and gross motor movement after controlling for BAC differences.

*Were there sex differences in the effects of alcohol and ED dose on cognitive and motor intoxication outcomes?*

In light of the above discussion, it is not surprising that there were no differences between male and female participants in cognitive performance according to the dose of alcohol and ED consumed, as the power of the analyses were reduced even further by breaking down the sample according to sex. There were differential effects of alcohol and ED on gross motor performance for female participants, with better gross motor movement when those in the moderate or high alcohol group consumed no EDs compared to when they consumed the high ED dose. Male participants' gross motor performance did not differ according to the amount of alcohol and ED consumed. In contrast, there were no differences between males and females in the dose-dependent effects of ED consumption when ingesting a moderate or high alcohol dose for fine motor movement and balance.

### 5.4.5 Physiological Intoxication Outcomes

#### Blood Pressure (BP): Diastolic

Analyses were conducted on the mean change in diastolic BP when recorded 30 minutes after commencing beverage consumption compared to the baseline recording (negative scores indicate a decrease in BP, positive scores indicate an increase in BP). The mean diastolic BP at baseline and 30 minutes for each alcohol group is displayed in Figure 75 according to the ED dose co-ingested. As evident in this figure, diastolic BP typically increased from baseline to 30 minutes, regardless of the alcohol group or ED dose consumed.

There was no significant effect of alcohol dose on the change in diastolic BP from baseline to 30 minutes after commencing alcohol consumption ( $p=.988$ ). However, the volume of ED ingested did significantly affect diastolic BP, regardless of the alcohol dose consumed,  $F(3, 81)=3.525$ ,  $p=.019$ . Specifically, placebo ED resulted in a greater increase in BP ( $M=+5.7$ ,  $SD=5.2$ ) relative to when two ( $M=+1.4$ ,  $SD=7.7$ ,  $p=.018$ ,  $g=0.66$ ) or three ( $M=+1.3$ ,  $SD=7.3$ ;  $p=.009$ ,  $g=0.71$ ) standard EDs were consumed. (These results suggest that consuming a moderate or high ED dose might reduce inflation in diastolic BP seen over time, regardless of whether alcohol was co-ingested.)

There was no significant interactive effect of alcohol group and ED dose ( $p=.805$ ), suggesting that the effect of ED on diastolic BP did not differ between the alcohol groups. After controlling for differences in BAC, the effect of ED on diastolic BP remained for the moderate alcohol group only ( $p=.070$ ). That is, there was a reduction in diastolic BP from baseline to 30 minutes after consuming the moderate alcohol dose with three standard EDs ( $M=-1.2$ ,  $SD=14.9$ ) relative to an increase in diastolic BP after consuming the moderate alcohol dose without any EDs ( $M=+9.0$ ,  $SD=15.4$ ,  $p=.065$ ,  $g=0.52$ ).

Analyses looking at sex differences in diastolic BP showed that males' and females' diastolic BP tended to differ according to the amount of alcohol and ED consumed,  $F(6, 72)=1.917$ ,  $p=.090$ . Follow-up analyses showed that diastolic BP did not differ for females according to the amount of alcohol and ED consumed ( $ps>.189$ ). In contrast, diastolic BP for males tended to differ according to the ED dose consumed, regardless of the alcohol dose consumed,  $F(3, 36)=5.807$ ,  $p=.002$ . Specifically, males tended to record increased diastolic BP when they consumed no EDs ( $M=+5.8$ ,  $SD=4.6$ ) or one standard ED ( $M=+3.8$ ,  $SD=6.5$ ) and decreased diastolic BP when they consumed two ( $M=-1.5$ ,  $SD=5.9$ ,  $p=.001$ ,  $g=1.38$  and  $p=.028$ ,  $g=0.85$  respectively) or three ( $M=-1.4$ ,  $SD=7.9$ ,  $p=.016$ ,  $g=1.11$  and  $p=.039$ ,  $g=0.72$  respectively) standard EDs.

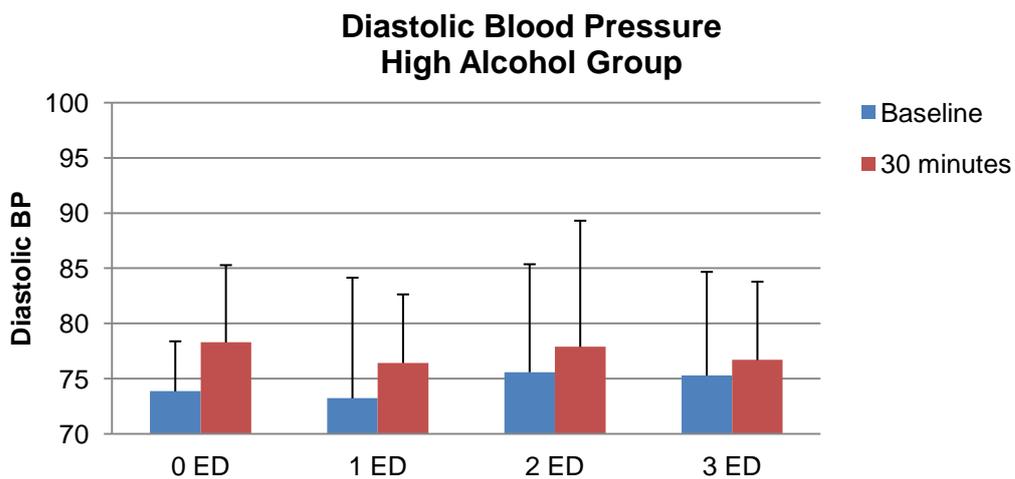
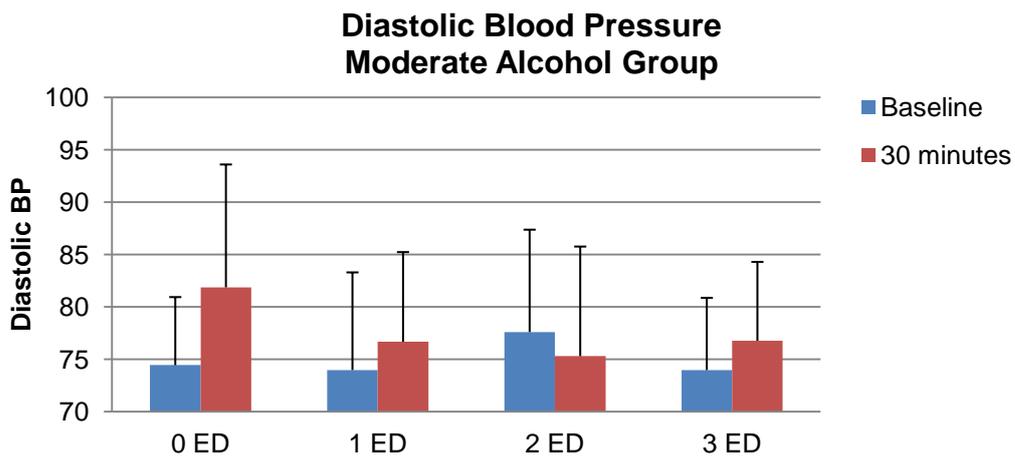
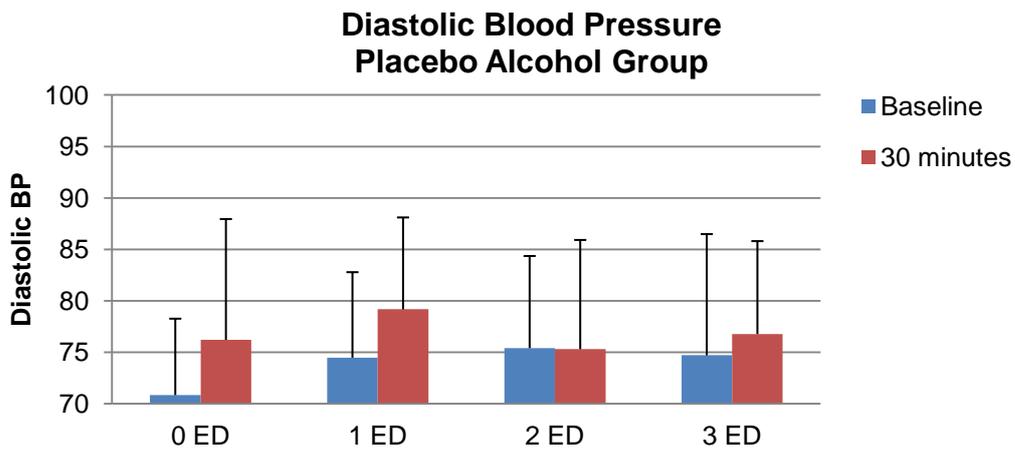


Figure 75. Mean diastolic blood pressure 30 minutes after commencing beverage consumption for the placebo (top panel), moderate (middle panel) and high (bottom panel) alcohol group according to the number of EDs co-ingested

### **Blood Pressure (BP): Systolic**

Like diastolic BP, analyses were conducted on the mean change in systolic BP when recorded 30 minutes after commencing beverage consumption compared to the baseline recording (negative scores indicate a decrease in BP; positive scores indicate an increase in BP). The mean change in systolic blood pressure at baseline and 30 minutes for each alcohol group is displayed in Figure 76 according to the ED dose co-ingested. As evident in this figure, systolic BP typically increased from baseline to 30 minutes, regardless of the alcohol group or ED dose administered.

There was no significant effect of alcohol dose on the change in systolic BP from baseline to 30 minutes after commencing beverage consumption ( $p=.989$ ), nor was there any significant dose-dependent effects of ED ( $p=.649$ ). Furthermore, there was no significant difference in systolic BP between the alcohol groups according to the dose of ED consumed, as evidenced by a non-significant alcohol and ED interaction ( $p=.934$ ). These results were supported by analyses which controlled for differences in BAC across the ED doses, with no significant difference in systolic BP according to ED dose for the moderate alcohol group ( $p=.899$ ) or the high alcohol group ( $p=.786$ ). Furthermore, there was no difference between males and females in systolic BP according to the dose of alcohol and ED consumed ( $ps>.123$ ).

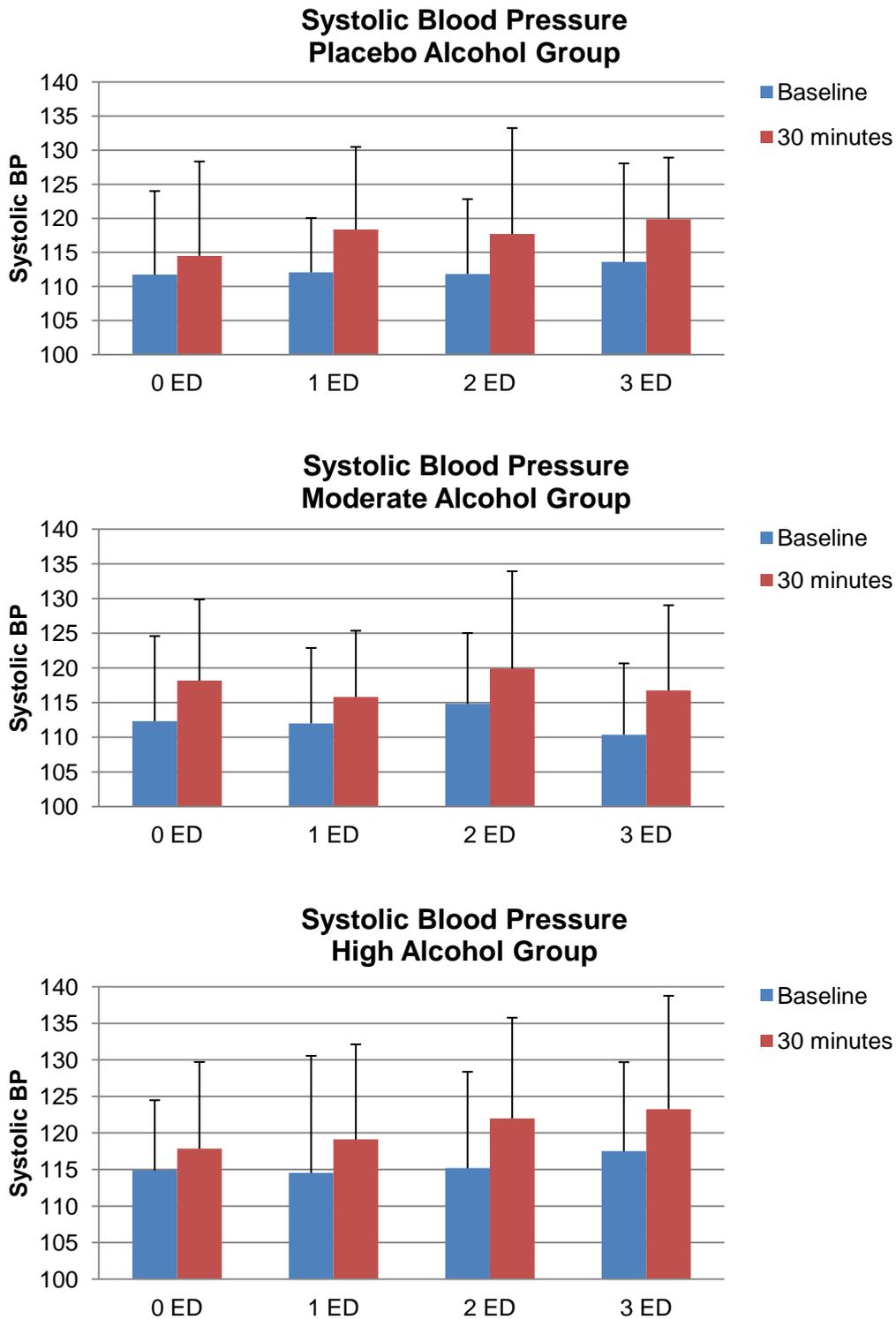


Figure 76. Mean systolic blood pressure 30 minutes after commencing beverage consumption for the placebo (top panel), moderate (middle panel) and high (bottom panel) alcohol group according to the number of EDs co-ingested

## Heart Rate (HR)

Analyses were conducted on the mean change in HR when recorded 30 minutes after commencing beverage consumption compared to the baseline recording (negative scores indicate a decrease in HR; positive scores indicate an increase in HR). The mean pulse (beats per minutes) at baseline and 30 minutes for each alcohol group is displayed in Figure 77 according to the ED dose co-ingested. As evident in this figure, mean HR typically decreased from baseline to 30 minutes, regardless of the alcohol group or ED dose administered.

There was no effect of alcohol dose on HR when averaged across the ED conditions ( $p=.374$ ). However, there were dose-dependent effects of ED on HR,  $F(3, 81)=4.462$ ,  $p=.006$ . Specifically, when participants did not consume any EDs ( $M=-2.8$ ,  $SD=5.3$ ) or consumed one standard ED ( $M=-2.5$ ,  $SD=5.3$ ,  $p=.027$ ,  $g=0.62$ ), HR decreased from baseline and when they consumed three standard EDs there was an increase in HR compared to baseline ( $M=+1.7$ ,  $SD=7.9$ ,  $p=.002$ ,  $g=0.67$ ).

There was no interactive effect of alcohol and ED on HR ( $p=.155$ ), suggesting that the change in HR found for ED dose was consistent across the alcohol groups according to the ED dose administered.

However, there tended to be significant ED dose-dependent changes in HR for the moderate alcohol group when analyses were conducted to statistically control for differences in BAC across the ED doses,  $F(3, 37)=2.710$ ,  $p=.061$ . Specifically, there was a significant decrease in HR from baseline when no ED ( $M=-4.2$ ,  $SD=9.0$ ) or one standard ED ( $M=-3.6$ ,  $SD=8.7$ ) were consumed with the moderate alcohol dose compared to a slight increase in HR from baseline when two EDs ( $M=0.5$ ,  $SD=8.2$ ,  $p=0.28$ ,  $g=0.55$  and  $p=0.51$ ,  $g=0.49$  respectively) or three EDs ( $M=0.5$ ,  $SD=8.7$ ,  $p=0.38$ ,  $g=0.53$  and  $p=0.63$ ,  $g=0.47$  respectively) were consumed with the same alcohol dose.

Similarly, there were significant dose-dependent effects of ED on HR for the high alcohol group after controlling for BAC differences across the ED doses,  $F(3, 35)=3.384$ ,  $p=.029$ . Specifically, HR increased from baseline when three standard EDs ( $M=5.7$ ,  $SD=13.0$ ) were consumed with the high alcohol dose, which contrasted with the decrease in HR from baseline when one standard ED ( $M=-3.1$ ,  $SD=12.7$ ,  $p=.007$ ,  $g=0.68$ ) or no EDs ( $M=-2.7$ ,  $SD=13.1$ ,  $p=.013$ ,  $g=0.64$ ) were consumed with the high alcohol dose.

There was no significant difference between males and females in the change in HR from baseline according to the dose of alcohol and ED consumed ( $ps>.311$ ).

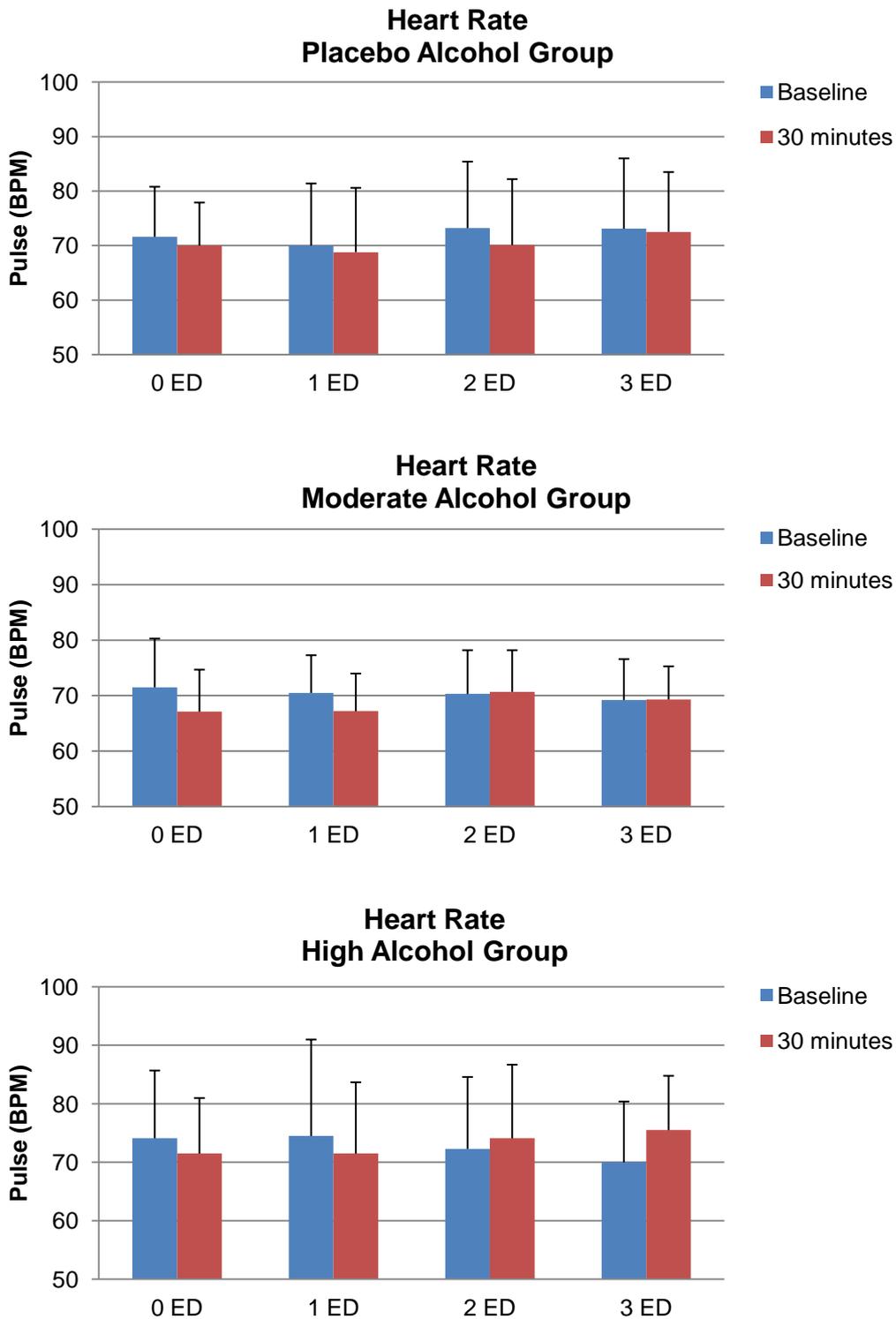


Figure 77. Mean heart rate in beats per minute (bpm) 30 minutes after commencing beverage consumption for the placebo (top panel), moderate (middle panel) and high (bottom panel) alcohol group according to the number of EDs co-ingested

## Summary of Physiological Intoxication Outcomes

It is important to note that BP typically increased over time and HR typically decreased over time. This pattern of results most likely reflects the test setting, where participants had a longer duration of rest prior to the post-beverage testing point. The following results should be interpreted in light of this pattern of results.

*What were the dose-dependent effects of alcohol on physiological intoxication outcomes (regardless of ED intake)?*

There was no significant effect of alcohol on diastolic and systolic BP or HR when these outcomes were averaged across the ED conditions, regardless of whether the alcohol dose was moderate or high.

*What were the dose-dependent effects of ED on physiological intoxication outcomes (regardless of alcohol intake)?*

Diastolic BP increased when no ED was consumed and decreased when two or three standard EDs were consumed, suggesting that a moderate or high ED dose might reduce inflation in diastolic BP seen over time, regardless of whether alcohol was co-ingested. In contrast, there were no ED dose-dependent effects on systolic BP. A decrease in HR observed after consuming no or one EDs was contrasted with a slight increase in HR after consuming three EDs, suggested that decreases in HR over time might be diminished by moderate or high ED consumption.

*What were the interactive effects of alcohol and ED dose on physiological intoxication outcomes? Were these interactive effects of alcohol and ED present after controlling for differences in BAC?*

There were no interactive effects of consuming alcohol and EDs on diastolic and systolic BP or HR.

However, when differences in BAC across the ED doses were controlled, there was a reduction in diastolic BP from baseline to 30 minutes after consuming the moderate alcohol dose with three standard EDs relative to an increase in diastolic BP after consuming the moderate alcohol dose without any EDs. These results suggest that, after controlling for differences in BAC, consuming alcohol with an ED dose that exceeds the recommended maximum daily intake (i.e., three standard EDs) may decrease diastolic BP relative to consuming alcohol without EDs. It should be noted that this effect was only evident when a moderate alcohol dose was consumed. There was no change in systolic BP for the moderate or high alcohol group after controlling for BAC differences.

There were ED dose-dependent differences in HR after controlling for BAC differences across ED doses. The moderate alcohol group showed a decrease in HR after consuming the moderate alcohol dose with no ED or the low ED dose and a slight increase in HR after consuming the same alcohol dose with a moderate or high ED dose. Similarly, the high alcohol group showed a decreased in HR after consuming the high alcohol dose with no ED or the low ED dose, and an increase in HR after consuming the same alcohol dose with the high ED dose. Thus, it appears that decreases in HR from

baseline after consuming alcohol with no ED or a low ED dose might disappear after consuming alcohol with a high ED dose, with the high ED dose resulting in an increase in HR, particularly when consumed with the high alcohol dose. It should be noted that the BP and HR results should be treated with caution, as it cannot be determined whether these changes result in any practical or clinically significant outcomes for the consumer. Furthermore, these results provide just a snapshot of the physiological outcomes at a set time point during the study. Comparison of the change from baseline was required to rule out existing variability in BP and HR between each participant's sessions and also between the participants themselves. However, the baseline measurement was taken at the commencement of the session (after a 10 minute resting period), while the 30 minute measurement was taken after the participant had been sitting for 30 minutes consuming the beverage. The fact that HR typically decreased over time, regardless of the treatment administered, suggests that a greater period of rest prior to recordings may be required to maximise the accuracy of outcomes. Thus, the present results may have been influenced by situational variables, making it difficult to calculate and untangle any true treatment effects.

*Were there sex differences in the effects of alcohol and ED dose on physiological intoxication outcomes?*

While females' diastolic BP did not differ according to the alcohol and ED dose consumed, males tended to have a greater increase in diastolic BP when they consumed no EDs or a low ED dose compared to when they consumed a moderate or high ED dose. There were no sex differences in systolic BP and HR.

#### **5.4.6 Behavioural Risk-Taking Outcomes**

##### **Driving Risk-Taking**

The percentage of time spent in excess of the speed limits was used as the primary indicator of risk-taking, with a higher percentage indicative of greater risk-taking (see Figure 78).

There was a moderate magnitude (but non-significant) increase in time spent speeding after consuming the high alcohol dose with no EDs ( $M=0.29$ ,  $SD=0.54$ ) compared to the placebo alcohol dose with no EDs ( $M=0.01$ ,  $SD=0.01$ ,  $p=.122$ ,  $g=0.76$ ), showing that the measure was sensitive to alcohol-induced impairment of risk-taking. However, the low rate of risk-taking across all treatment conditions should be noted here.

Analyses revealed no significant dose-dependent effect of alcohol on driving risk-taking when performance was averaged across the ED conditions ( $p=.533$ ), nor were there any significant dose-dependent effects of ED consumption ( $p=.201$ ). There was no significant interactive effect of alcohol and ED on the percentage of time spent speeding ( $p=.374$ ), suggesting that driving risk-taking did not differ between the alcohol groups according to the amount of ED consumed. This conclusion is supported by analyses controlling for differences in BAC across ED doses, with no significant ED dose-dependent differences in driving risk-taking for the moderate alcohol group ( $p=.302$ ) or the high

alcohol group ( $p=.258$ ). Furthermore, there was no significant difference in driving risk-taking by males and females according to the alcohol or ED dose consumed ( $ps>.308$ ).

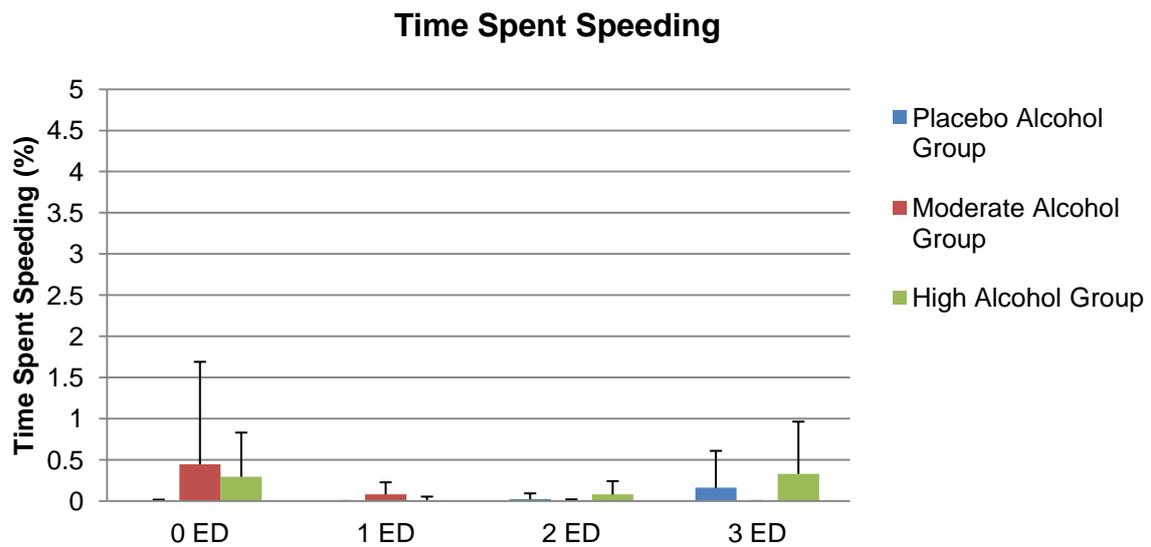


Figure 78. Mean time spent speeding (%) by each alcohol group according to the number of EDs co-ingested (error bars depict the standard deviation)

### Summary of Driving Risk-Taking Outcomes

*What were the dose-dependent effects of alcohol and ED on behavioural risk-taking outcomes?*

There was no dose-dependent effect of alcohol (averaged over the ED conditions) or ED (averaged over the alcohol groups) on driving risk-taking.

*What were the interactive effects of alcohol and ED dose on behavioural risk-taking outcomes? Were any interactive effects of alcohol and ED present after controlling for differences in BAC?*

There was no difference in driving risk-taking between the alcohol groups according to the amount of ED consumed. However, these results should be interpreted in the context of a very low overall rate of risk-taking by all participants, regardless of alcohol or ED dose, and the fact that there was only one measure of risk-taking.

*Were there sex differences in the effects of alcohol and ED dose on behavioural risk-taking?*

There was no difference between male and female participants in driving risk-taking according to the amount of alcohol and ED consumed.

## 5.5 Discussion

The aim of the present study was to determine the dose-dependent effects of alcohol and EDs, consumed independently and in combination, on BAC, perceived intoxication, objective cognitive and motor intoxication, physiological outcomes, and behavioural risk-taking. The following discussion will address each of these areas.

### **Does AED consumption change blood alcohol concentration (BAC), the primary measure of alcohol impairment which reflects the disposition and fate of alcohol in the body, evident via an increased or decreased BAC after consuming AED relative to alcohol?**

The results of the present study showed that consuming a moderate alcohol dose with one, two, or three standard EDs generally resulted in a significant decrease in BAC compared to when the same alcohol dose was consumed without any active EDs (peak BAC of .068%). Similarly, decreases in BAC were evident after consuming the high alcohol dose with an ED dose which matched or exceeded the recommended maximum daily intake (i.e., two or three standard 250mL EDs) relative to consuming the same alcohol dose without any active EDs (peak BAC of .080%).

Previous research has shown that alcohol absorption is impacted by the speed of gastric emptying (196), with the presence of food delaying the emptying of the stomach, decreasing alcohol absorption, and reducing BAC. For example, it has been found that ingesting alcohol after consuming breakfast relative to an overnight fast results in reduced BAC and lower ratings of intoxication (197). Following on from this, it has also been suggested that the composition of the beverage mixed with alcohol may also impact on gastric emptying. Specifically, those mixers which *do not* contain natural sugars (i.e., diet beverages) may have a faster rate of gastric emptying, increasing the rate of absorption and resulting in higher peak intoxication, as evident by a higher BAC. Previous field research with a sample of bar patrons has shown that those who consumed sugar-free cola with alcohol had a mean BAC higher than those who had consumed normal cola mixers with alcohol, non-caffeinated mixers with alcohol, and alcohol only (.133% versus .097%, .092%, and .073% respectively), with the number of diet cola-caffeinated beverages consumed significantly associated with BAC (164). Similarly, Marczinski and Stamatos (198) found that BACs were significantly higher after consuming alcohol with a diet drink compared to a normal sugar-sweetened drink, with greater impairment of objective intoxication (i.e., mean RT) when the former was consumed. However, direct causal attributions regarding the physiological mechanisms of alcohol, caffeine, and sugar metabolism could not be made based on these studies as there was no direct assessment of the rate of gastric emptying. Research which has incorporated direct assessment by measuring gastric emptying by an ultrasound has indicated that consuming a diet, artificially sweetened mixer significantly decreased gastric half-emptying time. Similar to previous studies, BACs were also higher after consuming the artificial sweetened mixer compared to the 'regular' sugar-sweetened mixer (199).

Together, these studies suggest that the body treats sugar-sweetened beverages almost like a food, resulting in a slower rate of alcohol metabolism and a lower BAC. The placebo ED mixer used in the present study was sugar-free soda water with artificially sweetened syrup (sucralose Splenda®); there

were no active ingredients in the placebo beverage. In contrast, the active ED conditions contained approximately 27g sugar per 250mL portion, meaning that in the high ED conditions, participants consumed 81g sugar. The present results suggest that the active EDs administered in this study may have functioned similar to other standard sugar-sweetened mixers, lowering the rate of gastric emptying and thus decreasing absorption and resulting in a lower BAC.

As gastric emptying is thought to occur at a rate of 2 to 3 calories (kcal) per minute (200), it is not surprising that BAC was lower after consuming the active ED with alcohol compared to consuming the same amount of alcohol alone with the artificially sweetened mixer. This interpretation is supported by examining the dose-dependent effects of ED, as lower BACs were evident when the moderate alcohol dose was consumed with three standard EDs relative to when the ED dose matched or was less than the recommended intake (i.e., two or one standard ED).

#### *Limitations and Future Research*

As the purpose of this study was to investigate the effects of the ED beverage as a whole, we could not control the quantities of specific ingredients to determine their role in changes in BAC. Future research controlling the quantity of sugar (and other ingredients) across the ED conditions will elucidate whether changes in BAC can be directly attributed to the changes in sugar content or other ingredients, or to the beverage as a whole. At present, we cannot presume that it is only the presence of sugar in EDs which impacts on BAC. For example, animal studies have showed that oral doses of 10mg/kg (equivalent to 700mg for humans), 20mg/kg, 60mg/kg, or 100mg/kg caffeine combined with, or consumed 15 minutes prior to, 0.8g/kg to 4.8g/kg ethanol caused a dose-dependent increase in BAC, particularly in the latter condition (201). Furthermore, the stomachs of rats treated with ethanol and caffeine have been found to be of a larger volume and contain more ethanol than those treated with ethanol alone. These results suggest that caffeine can decrease BAC through delays in gastric emptying. However, it should be noted that several human studies have shown no significant difference in BAC when alcohol was consumed with caffeine relative to without caffeine (e.g., 202). Similarly, the effect of another primary ED ingredient, taurine, on human metabolism on alcohol remains relatively unknown, although there are animal studies showing no effect of taurine exposure on blood alcohol concentration of rats (203, 204).

Thus, further research is required clarifying the independent effects of the primary ED ingredients on alcohol metabolism. Furthermore, we need to consider the interactive effects of the active ingredients, as the effects of one ingredient may be increased or decreased by the presence of another, or both ingredients might have an additive effect. For example, there is evidence to suggest that caffeine (approximately two to three cups of brewed coffee) disrupts glucose metabolism (205). Thus, it may be that gastric emptying and alcohol absorption is impacted by the independent effects of the primary ED ingredients and/or the interactive effects of these ingredients as a whole within the beverage. Future objective research assessing the independent and interactive effects of the primary ED ingredients on alcohol metabolism is required, with direct assessment of alcohol absorption and elimination via measurement of the rate of gastric emptying.

### *Implications for Consumers*

This is the first study to examine the dose-dependent effects of ED on alcohol and thus provides the first evidence that absorption of alcohol might alter according to whether ED is used as a mixer. Participants' mean BAC was .068% 30 minutes after ingesting 0.50g/kg alcohol with a non-sweetened carbonated mixer. In contrast, participants' mean BAC was .045% after ingesting the same alcohol dose but with three standard EDs. Thus, the present results suggest that BAC may be higher when artificially sweetened mixers are used as opposed to when naturally sweetened ED mixers are used. As these results reflect previous research showing that consumption of naturally sweetened alcohol mixers (as opposed to artificially sweetened mixers) result in lower BAC, the outcomes suggest that lower BAC may not be specific to EDs and may be apparent for all naturally sweetened alcohol mixers. Further research is required to confirm the specific role of sugar in changes in BAC following ED consumption and confirm that comparable changes are evident when people ingest other naturally sweetened mixers. These results should also be interpreted in light of the following outcomes (see below) which indicate that AEDs generally do not alter perception of intoxication or performance outcomes after controlling for differences in BAC.

### **Does AED consumption cause an underestimation of perceived intoxication, as evident via reduced ratings of intoxication after consuming AED relative to alcohol?**

The aforementioned ED-dose dependent difference in BAC also has important implications for consumers in regards to their perception of intoxication, in regards to whether consumers' perceive an equivalent level of intoxication when AED versus alcohol is consumed. The aforementioned research (198) showed no difference in ratings of perceived intoxication when artificially sweetened versus naturally sweetened mixers were consumed. While the researchers concluded that there was no difference in perception of intoxication, the researchers did not statistically control for the fact that BAC was higher when artificially sweetened drinks were consumed. In the present study, consumption of the high ED dose appeared to lower perception of intoxication relative to when no ED was consumed, or when a low or moderate ED dose was consumed, regardless of the amount of alcohol consumed. However, this estimation may have accurately reflected actual intoxication. This conclusion was supported when we controlled for differences in BAC across the ED conditions, as there was no significant difference in the rating of intoxication or rating of perceived alcohol intake when participants consumed alcohol with or without EDs, regardless of the volume of alcohol or volume of ED. These results suggest that *after controlling for differences in BAC, consumers typically do not differ in their estimation of their level of intoxication when they consume alcohol with ED relative to when they consume alcohol alone, regardless of whether they ingest one, two or three EDs.*

The present study was the first to assess the dose-dependent effects of ED on perceived intoxication; all previous AED research has involved the administration of a single ED dose (typically one standard ED) with either one or several alcohol doses (74, 95, 157, 159, 206). Furthermore, this study was the first to introduce a direct self-report measure of perceived intoxication; typically perception of intoxication has been inferred from reports of perceived alcohol intake (also administered in the

present study) or ratings of physiological (e.g., headache) and psychological (e.g., energetic-lethargic) outcomes. Those previous studies which have adopted the former method have revealed no significant difference in reported alcohol intake when alcohol versus AED is consumed. As such, the current body of literature and the present results generally indicate that AED, relative to alcohol, does not impact on perceived intoxication.

All of the existing literature has focused on perception of alcohol intoxication, be it through self-report of perceived intake or physiological and psychological outcomes. However, there has been no measurement of participants' perceived intake of ED. This is important for two reasons: (i) to confirm that ED placebo manipulations are successful and differences between placebo and active ED conditions are not just the result of participants' expectations of ED effects, and (ii) to see whether participants can accurately detect how many EDs they have consumed with alcohol. In regards to the former, participants reported consumption of approximately one standard ED in the placebo ED condition, suggesting that the placebo ED manipulation was successful. In regards to the latter, we found that after statistically controlling for differences in BAC across the ED conditions, participants who had consumed the moderate alcohol dose could not distinguish between consuming no ED, one standard ED, two standard EDs, or three standard EDs. After having the high alcohol dose, participants could detect the difference between the moderate ED dose and the low ED or no ED dose, but could not tell the difference between consuming an ED dose in excess of the recommended daily intake (i.e., three standard EDs), and consuming a moderate, low or no ED dose. These results suggest that consumers have a poor ability to discriminate different ED doses when consuming alcohol.

#### *Limitations and Future Research*

Perceived intoxication ratings were higher in the active alcohol conditions relative to the placebo alcohol conditions and reported alcohol intake was greater in the high alcohol dose group relative to the placebo alcohol dose group. These differences between the alcohol groups introduce the possibility of alcohol expectancy effects, whereby participants' belief that they were more intoxicated after having the moderate and high alcohol doses might have lead them to consciously or subconsciously alter their behaviour on the tasks to match these expectations. However, it should be noted that participants in the placebo alcohol group perceived some degree of intoxication and also reported an average intake of just over one and a half standard drinks, suggesting that the placebo alcohol manipulation was successful and that participants in this group believed they had consumed alcohol. Alcohol placebos are restricted in terms of the amount of alcohol a participant can reasonably be lead to expect, as participants are generally familiar with the cues of alcohol consumption. Even if the taste and smell of active and placebo beverages can be matched, the somatic and physiological experience of alcohol consumption cannot be induced. However, we should note that there was no significant difference in perceived intoxication (subjective intoxication ratings and reported alcohol intake) according to the ED dose administered in the active alcohol groups, thus suggesting that alcohol expectancy may not have differed for the AED versus alcohol conditions.

Following on from this idea of expectancy, participants were explicitly informed they may consume up to six standard alcoholic drinks and three standard EDs during each session. Previous research has indicated that consumers have certain expectancies regarding the effects of AED; American college athletes reported a greater expectation of risk-taking behaviour in future AED relative to alcohol drinking sessions. This is not surprising given that ED marketing is focused on thrill-seeking and risk-taking behaviour (124). Furthermore, a proportion of AED consumers report faster intoxication as a motivation for AED consumption (128). Thus, it may be that consumers have pre-conceived ideas about how AED, relative to alcohol, may impact on their state of intoxication and subsequent behaviour. However, there have been no studies objectively assessing how expectancies regarding the effects of AED impacts on ratings of perceived and actual intoxication. Such research could clarify to what degree ratings of perceived intoxication are influenced by: (i) the pharmacological effects of AED, and (ii) expectancies regarding the effects of AED.

### *Implications for Consumers*

It has been suggested that the stimulant effects of consuming EDs (i.e., enhanced alertness and endurance) mask the depressant effects of alcohol (i.e., drowsiness, fatigue), resulting in consumers underestimating their level of intoxication relative to when they consume alcohol alone (95). This underestimation of intoxication has been argued to lead to increased alcohol intake, longer drinking periods, and a reduced ability to accurately detect level of impairment, resulting in increased risk-taking. *Like the majority of the previous research, the present study does not support the inference that AED results in an underestimation of intoxication relative to consuming alcohol alone.*

However, there are serious implications of participants' apparent inability to discriminate different ED doses when consuming alcohol. Consumers are typically informed of the alcohol and caffeine content of pre-mixed beverages due to packaging requirements. However, in the case of hand-mixed AED use consumers may purchase AED beverages in a licensed venue from bar staff and thus may not be aware of volume of ED in their beverage. This situation is all the more likely when AEDs are purchased in a 'jug' which might contain several standard 250mL ED servings. The results of the present study show that consumers have particular difficulties in detecting the volume of EDs when intake exceeds the recommended daily maximum of two standard EDs, with participants believing they have only consumed on average one standard ED. *These results suggest that consumers in the night-time economy may thus be unable to accurately detect and monitor their ED intake if there is no visible indication of the servings consumed.* This is particularly concerning considering that previous research showed that 33% of a community sample of Australian AED consumers typically ingested three or more standard EDs during AED drinking sessions (129). Further research is required to confirm whether consumers still evidence difficulties in discriminating their ED intake at higher doses than those administered in the present study. Such research may need to incorporate field-based assessment of bar patrons due to the potential ethical implications of administering doses considerable higher than the recommended maximum daily intake.

### **Does AED consumption cause an increase or decrease in actual intoxication outcomes, as evident via greater or lesser impairment on cognitive and motor performance outcomes after consuming AED relative to alcohol?**

There was no difference in cognitive performance when alcohol (moderate or high dose) was consumed without EDs relative to when it was consumed with EDs. These results suggest that there is no difference in cognitive intoxication outcomes on the specific measures administered in this study following AED versus alcohol consumption at these doses. These results match the majority of previous AED studies (74, 95, 157, 159), which have generally shown no significant difference in performance on cognitive measures after consuming an alcohol dose (0.6g/kg-1.0g/kg) with a low ED dose (approximately 250mL per 70kg person), with the exception of two studies which revealed reversal of alcohol-induced impairment of reaction time on cued go/no-go task (74) and greater accuracy and faster completion of a Stroop task after consuming AED (157).

In regards to motor performance, it appeared that *consuming alcohol with an ED dose that exceeded the recommended maximum daily intake (i.e., three standard EDs) improved balance compared to consuming the same dose of alcohol consumed without EDs*. This contradicts past research showing that increased body sway after consuming alcohol (0.6g/kg) was not reduced by co-ingestion of a similar dose of caffeine (200mg) to that administered in the present study (i.e., 240mg caffeine in three standard EDs) (207). However, this past research only involved administration of one ED ingredient, and thus findings cannot be generalised to the whole ED beverage. However, it should be noted that in the present study, AED-improvement in balance was not evident when the high alcohol dose was consumed, suggesting that ED intake (and the volume) does not impact balance when a high alcohol dose is consumed.

Consumption of EDs (regardless of alcohol intake) tended to improve gross motor movement, but only when the low ED dose was consumed; consumption of ED intake equivalent to, or in excess of, the recommended daily maximum intake of two standard EDs saw this improvement in motor performance disappear. However, these ED-induced differences in gross motor movement may have reflected actual differences in intoxication. *After statistically controlling for differences in BAC across the ED conditions, there was no difference in gross or fine motor movement according to whether the moderate or high alcohol dose was ingested alone or with ED*. These results align with previous research (159) which showed no significant difference in motor coordination, as measured using the Purdue Pegboard Task, when alcohol versus AED was consumed. However, it should be noted that there were sex differences in the effects of alcohol and EDs on gross motor movement in the present study. Specifically, females performed worse after consuming the moderate alcohol dose with one, two, or three standard EDs relative to having the alcohol dose alone. Some of the effects disappeared with the high alcohol dose, with females only performing worse after having two or three standard EDs with alcohol relative to have alcohol without EDs. Males did not differ in their performance according to the alcohol and ED dose consumed. These results suggest that there may differential dose-dependent effects of consuming AED relative to alcohol for males and females.

### *Limitations and Future Research*

It should be noted that cognitive processing incorporates a range of functions and skills, including attention, speed of processing, working memory, problem-solving, decision-making, nonverbal and verbal memory, verbal reasoning, psychomotor function, and so on. The present study only assessed several of these aspects of functioning, including attention, psychomotor function, and decision-making. Thus, while the current results suggest that there is no difference in performance following AED and alcohol consumption on these specific measures, it cannot be definitively concluded that there is no additional impact of consuming AED on cognitive performance on the whole. This conclusion is reinforced by the aforementioned previous research showing that AED may selectively impact on certain aspects of functioning.

This also restricts comparisons between studies, as researchers might be assessing the effect of AED and alcohol on different processes. While the rise and fall in BAC over time can make it difficult to undertake lengthy testing at peak intoxication, future studies should be focused on undertaking comprehensive assessment of cognitive and motor performance via administration of standardised validated test batteries, so that more definitive conclusions can be drawn across studies regarding the relative effect of AED and alcohol on cognitive and motor intoxication.

However, the most important consideration for any conclusions regarding AED-induced changes in actual intoxication is the general absence of any effect of alcohol consumption on cognitive performance when averaged across ED conditions. This absence of difference in cognitive performance after AED relative to alcohol consumption might: (i) be due to the methodology of the study (e.g., insufficient alcohol dose to cause impairment on the task or low task sensitivity to detect alcohol impairment), (ii) reflect low statistical power to detect effects unless they were very substantial, or (iii) (i) accurately reflect how ED impacts on actual alcohol impairment.

The first explanation is less likely due to the aforementioned research demonstrating the sensitivity of the tasks to alcohol-induced impairment following consumption of similar doses to those administered in the present study. Furthermore, analyses generally showed that the tasks detected alcohol effects when comparing performance after the high alcohol dose with no EDs relative to the placebo alcohol dose with no EDs. In regards to the second explanation, the aforementioned analyses showed that nearly half the cognitive measures only detected small magnitude alcohol-induced impairment in performance, with the difference between the two conditions only reaching statistical significance for one outcome measure (RVP mean latency). These results indicate that there may be an issue surrounding statistical power as opposed to an issue with the design of the study and the selection and administration of tasks. Thus, it is not clear whether the absence of treatment effects can be attributed to a lack of statistical power or actually accurately reflect the interactive effect of AED relative to alcohol alone. *As such, we would recommend that firm conclusions regarding the relative effect of consuming AED versus alcohol on actual intoxication outcomes cannot be made until these findings are replicated in future research.*

### *Implications for Consumers*

The present results suggest that consuming alcohol with EDs generally does not change cognitive performance relative to when alcohol is consumed without EDs. These results suggest that consumers cannot presume that consuming these stimulant drinks with alcohol will result in better reaction time, greater attention, reduced behavioural impulsivity, and improved driving performance, compared to when alcohol is consumed alone. However, caution should be exacted when interpreting these results in the context of the real-life drinking experience as the low statistical power made it difficult to detect differential effects of alcohol consumed with or without EDs which were not substantial. In regards to motor performance, an improvement in balance was evident when the moderate alcohol dose was consumed with three EDs relative to no EDs, and females showed worse gross motor movement after co-ingesting the moderate or high ED dose with alcohol relative to having alcohol alone. However, the practical significance of these results needs to be confirmed; these results cannot be translated to presume that ingesting a moderate alcohol dose with three EDs results in a negative balance-related outcomes (e.g., falls or other unintentional injuries).

### **Does AED consumption cause an increase or decrease in physiological indices of intoxication, as evident via an increase or decrease in HR and BP after consuming AED relative to alcohol?**

There was no impact of consuming alcohol with EDs relative to alcohol without ED on systolic BP. In regards to diastolic BP, the results showed that consuming alcohol with an ED dose that exceeds the recommended maximum daily intake guidelines (i.e., three standard EDs) decreased BP relative to consuming alcohol without EDs. However, this effect only occurred when a moderate alcohol dose was ingested.

The results of the present study partially match previous research (202). Like the present study, Rush et al. (202) found that co-ingesting alcohol (0.5g/kg and 1.0g/kg) with caffeine (250mg and 750mg per 70kg person) reduced increases in diastolic BP seen when alcohol was consumed alone. In contrast to the present study, Rush et al. (202) also reported this same pattern of results for systolic BP. However, caution should be exacted when comparing the results of these studies, as the study was restricted to examining the effect of one ED ingredient, and the other ingredients in EDs may impact on blood pressure. For example, previous research has shown that taurine supplementation can be used therapeutically to lower BP (see (208) for a review). However, there are few human studies of the acute effects of taurine doses similar to those ingested in EDs, with the exception of Bichler (183), who showed no significant change in mean arterial BP after co-ingesting caffeine and taurine. Thus, the effect of the individual ingredients and the beverage as a whole requires further clarification. However, *overall the results of the present study suggest that AED may reduce diastolic BP but only when a moderate alcohol dose is consumed with a high ED dose.* It should be strongly emphasised that the practical and clinical significance of these changes for consumers cannot be determined from the present results.

In regards to HR, the results showed that the decrease in HR seen when alcohol was consumed alone or with a low ED dose tended to disappear when consuming alcohol with an ED dose in excess

of the recommended daily intake guidelines, with the combination of the high ED dose and alcohol increasing HR, particularly after the high alcohol dose. These results contradict past research by Rush et al. (202). Firstly, Rush et al. (202) found that HR dose-dependently increased after consuming alcohol (0.5g/kg and 1.0g/kg) alone. Secondly, Rush et al. (202) found that consuming caffeine (250mg or 500mg per 70kg person) did not impact on these alcohol-induced increases in HR. Similarly, previous research has shown that consuming alcohol (0.6g/kg) with caffeine (200mg or 400mg) does not impact on HR relative to consuming a placebo beverage, despite an increase in the number of beats per minute when alcohol was consumed alone relative to placebo (207). However, these studies only examine the effects of caffeine and thus have limited generalisability to the ED beverage as a whole. Acute consumption of caffeine typically lowers HR in caffeine naive consumers; habitual caffeine users show tolerance through attenuation of these effects (209). However, previous research suggests that EDs may have a differential effects on HR, although the literature is somewhat equivocal regarding how EDs impact HR (55, 76, 102). *In light of the discrepancy with past research, the present results indicating that a high ED dose combined with alcohol might increase HR relative to no or a low ED dose combined with alcohol should be treated with caution.*

#### *Limitations and Future Research*

It should be noted that sessions were conducted at different times of day, with participants potentially having different start times for their sessions. Previous research has shown that BP is highest mid-morning and falls throughout the day, rising again in the early hours of the morning before waking (210). Future research should involve a consistent session start time to control for the effects of circadian rhythm on physiological outcomes and performance in general.

Furthermore, the data presented here reflects only BP and HR recorded after the initial beverage absorption period. Thus, these findings might not be generalisable across the ascending and descending limb of the BAC curve. Caffeine is generally thought to reach peak in the blood between 30 and 60 minutes after consumption (211). Physiological parameters were assessed in the present study at the former time point. However, we cannot presume that peak caffeine levels were reached at this point as caffeine metabolism was not assessed throughout the study. Thus, further clarification is required regarding the relative effects of AED and alcohol consumption on BP and HR throughout the whole intoxication experience. This could be achieved by using ambulatory blood pressure monitoring, a non-invasive automated technique whereby BP is measured every 15-30 minutes over an extended period (typically 24 hours). Furthermore, more sophisticated HR outcomes could be adopted (e.g., heart rate variability: oscillations in the interval between consecutive heart beats) or ambulatory electrocardiogram monitoring could also be used to assess for arrhythmias post-AED consumption. Such research would increase the clinical significance of outcomes, particularly in light of consumer reports in previous survey research of heart palpitations following AED consumption (129). Ambulatory monitoring would also reduce the risk of “office or white coat hypertension”, whereby an elevation of BP may be evident in a clinic setting relative to normal ambulatory or self-measured BP due to increased alertness and arousal induced by the setting (212).

### *Implications for Consumers*

The results suggest that there are cardiovascular changes when AED is consumed relative to alcohol depending on the dose of alcohol and ED consumed. However, these results should be treated with caution when considering the implications for AED consumers, as we cannot confirm whether the changes in BP and HR translate into clinically significant and meaningful risk for consumers. Furthermore, these measures were taken in an artificial environment, thus reducing the generalisability to real-life AED consumption. As there are a numerous factors which can impact on changes in physiological outcomes after alcohol consumption (e.g., speed of consumption, dose, genetic predisposition to alcoholism) (213), it is not possible to apply the current results to all situations of AED consumption.

### **Does AED consumption cause an increase in behavioural risk-taking, as evident via an increase in risky behaviour on the driving simulator task after consuming AED relative to alcohol?**

There was no difference in behavioural risk-taking when alcohol was consumed with ED (regardless of the volume) relative to when alcohol was consumed without ED. These results match previous research (170) that revealed no difference in risk-taking behaviour on the computerised Balloon Analogue Risk Task after consuming alcohol (.05g/kg) with 3.57mL/kg ED (approximately one standard ED per 70kg person) relative to when the same alcohol dose was consumed without ED. It should be noted that this study did reveal increased risk-taking after active ED consumption relative to placebo ED consumption, regardless of whether alcohol was consumed. However, the results of the present study contrast with self-reported risk-taking behaviour by AED consumers. For example, a community sample of Australian AED consumers reported lower odds of risk-taking in AED relative to alcohol drinking sessions (129). In the survey arm of the study, it was revealed that AED consumers engaged in greater risk-taking when consuming alcohol only relative to when consuming AEDs. In contrast, a field study showed that bar patrons have a four-fold increased likelihood of reporting an intention to drive while under the influence of AED (127). Consequently, the results of the present study need to be treated with caution due to the mixed results in the previous research.

### *Limitations and Future Research*

There were a number of limitations with the measurement of behavioural risk-taking. It should be noted that there was an absence of alcohol treatment effects on driving risk-taking when performance was averaged across the ED conditions. However, analyses revealed that there was a non-significant moderate magnitude increase in risk-taking when, in the placebo ED condition, the high alcohol dose was consumed relative to the placebo alcohol dose. These results suggest that this measure should be sensitive to detect ED effects on alcohol-induced impairment.

Overall, there were very low rates of risk-taking, regardless of alcohol and ED intake. This general absence of risk-taking could be due to the fact that participants received reimbursement for task participation. Reimbursement for performance was provided as risk-taking in real-life has consequences, positive and negative. However, previous research has shown that alcohol-induced

impairment of performance can disappear when participants receive positive reinforcement (e.g., monetary reimbursement) for showing unimpaired performance (186). It is argued that participants become hyper-vigilant when they think they have consumed alcohol and consequently compensate for anticipated poor performance (112). Consequently, we need to undertake further research to see whether these results are replicated when the reimbursement is varied or removed and when other measures of risk-taking are administered.

#### *Implications for Consumers*

The present study would suggest that consumers do not differ in their level of driving risk-taking when alcohol is consumed with ED relative to without ED. However, these results need to be interpreted in light of the potential limitations of the methodology, including the fact that only one measure of risk-taking was included. Furthermore, behaviour was assessed in an artificial, laboratory environment. Even though driving simulator performance has been validated against real-world driving performance (131), there are potential influences (e.g., drinking peers) in the natural drinking environment which might impact on performance. Consequently, these results should be treated with caution when drawing inferences regarding the impact of AED consumption on driving risk-taking in real-life.

## 6. DISCUSSION AND RECOMMENDATIONS

The purpose of this project was to address well-known gaps in the Australian evidence base concerning the co-ingestion of alcohol and energy drinks. While national surveys report stable trends in population levels of alcohol consumption, alcohol-related emergency department presentations continue to rise (3). In particular, there have been notable increases over the past fifteen years in alcohol-related emergency department presentations among people aged 16-24 in NSW (4). The nature of young people's alcohol consumption in the night-time economy, particularly high levels of risky drinking among certain population subgroups, may be one reason for rising alcohol-related harms. A trend that may be associated with increased intoxication and alcohol-related harms is the mixing of alcohol with energy drinks, but it was identified that there is currently insufficient evidence about this consumption behaviour in Australia. In particular, it was identified by NSW Health that it is unknown how widespread AED use is in NSW, how AEDs are being consumed, who are consuming them, what harms are caused by their use and how widespread these harms are experienced. To fill these evidence gaps we conducted a comprehensive literature review, scoped the current data monitoring systems to ascertain the impact of AEDs on the NSW health system, interviewed young people in NSW who currently consume alcohol (the target demographic of AED consumers) and conducted an experimental study to gain objective information about the health, cognitive and risk-taking consequences of AED use. This chapter briefly summarises the findings of the four study components in the context of the study research questions and the broader literature on AEDs.

**Research Question 1: What is the current Australian and international evidence of the effects of mixing alcohol and energy drinks? What are the gaps in the evidence? What regulations nationally and internationally have been imposed on energy drinks when intended to be consumed with alcohol?**

AEDs became popular in the early 2000s and, given their relative newness, evidence of their popularity, contexts and patterns of use, and harms, is not well established. However, the AED literature is growing quickly, particularly in North America. Prevalence estimates suggest that between 15% and 50% of university students have used AEDs in the past month, while only two available Australian studies found that nearly half of a community sample and 70% of regular ecstasy users had used an AED in the past six months. AED consumers in North American studies are more likely to be Caucasian, male and younger (18-30 years), but little is known about the socio-demographic characteristics of Australian AED users. Both local and international data suggests that AEDs users consume these beverages fortnightly to monthly and drink approximately three AEDs per session; but there is also some evidence to suggest that a smaller group of AED users are consuming these beverages more regularly and at higher quantities. Vodka and Jagermeister® are the most popular mixers for EDs, and AED consumers are more likely to hand-mix these beverages than purchase pre-mixed AEDs. AEDs are most popular for consumption in licensed venues, but are also regularly consumed within private homes.

International survey research suggests that AED users are more likely to exhibit riskier drinking practices, including the tendency to consume alcohol more frequently and consume higher quantities of alcohol per session, relative to non-AED users. Survey research also shows that AED users display a higher propensity for risk-taking and engagement in more risk-taking behaviours. However, it is unclear whether this is because people high in risk-taking propensity are attracted to AED consumption and/or whether AED consumption causes increases in risk-taking behaviour and this was one of the key research questions of the current study.

The four primary benefits of AED use elicited through self-reported surveys with AED users in Australia and internationally are: a) stimulation, wakefulness and energy; b) taste; c) reduced inebriation; and d) increased intoxication. However, despite consumers self-reporting reduced inebriation and the facilitation of a more alert intoxication from AEDs, international experimental studies have found that combining EDs with alcohol does not alter consumers' *actual* intoxication levels or improve performance and motor coordination. However, some research suggests that AED consumption does increase *perceptions* of stimulation and reduce *perceptions* of fatigue relative to alcohol only. Consequently, it has been argued that AEDs change the nature, as opposed to the intensity, of intoxication. However, it should be noted that several studies have failed to find an effect of AEDs on perceptions of stimulation and mental fatigue, and subsequently this was another of the current study's key research questions. A number of studies have examined whether AEDs enable the consumption of higher levels of alcohol as reported by consumers; however, findings are inconclusive with some studies showing that AED users self-report consuming more alcohol during AED sessions relative to alcohol-only sessions, while others show the opposite. We also sought to shed more light on these findings.

Self-reported side-effects associated with AED consumption in previous survey studies include: a) dehydration and a worse hangover (self-reported as worse relative to alcohol-only sessions); b) sleeping difficulties; and c) physiological impairment such as increased heart rate, palpitations, gastrointestinal upset, vomiting and nausea. While extremely rare, deaths following ED and AED consumption have occurred, but are often suspected as a result of heart failure in those with a predisposed heart condition.

There are mixed findings regarding the relationship between AED consumption and risk-taking, with some US research showing that participants expected greater engagement in risk-taking during sessions of AED use compared to sessions of alcohol use, and an Australian study reporting less engagement in risk-taking behaviour in AED users relative to alcohol-only sessions during the preceding six months. This was another of the key research questions of the current study.

Australia and New Zealand have the strictest regulations internationally in terms of the amount of caffeine permitted in EDs. The Australia New Zealand Food Standards Code (15) specifies that EDs may contain a maximum of 320mg/L caffeine, or 80mg per standard 250mL ED. As such, EDs marketed in Australia have a similar caffeine content to a standard cup of instant coffee. Restrictions also exist on the amount of taurine and glucuronolactone permitted in EDs in Australia. Canada has the strictest labelling on EDs of all countries, with a recent reclassification of EDs from a natural health

product to a food to be regulated under the Food and Drugs Act resulting in the requirement of warning labels on the packaging of EDs to state 'do not mix with alcohol', 'high source of caffeine', and 'not recommended for children, pregnant/breastfeeding women, individuals sensitive to caffeine' (this last statement is included on the cans of most EDs). As part of this reclassification, Health Canada also now requires energy drink companies to submit annual data on sales, consumption and adverse events in relation to energy drinks (122, 173).

In relation to the regulation of AEDs, the US and Mexico have the strictest regulations, with the US having banned the sale of pre-mixed AEDs, and Mexico having prohibited the sale of AEDs in licensed venues. The only regulation of AEDs in Australia exists in Perth, where since May 2011 it has been prohibited to sell liquor mixed with EDs after midnight in all late-night licensed hotels, taverns, small bars. However, EDs and alcoholic drinks can still be purchased separately, meaning that patrons can potentially hand-mix these products themselves or continue consuming EDs and alcohol in the same session, which is likely to undermine the intention of this policy.

The main gaps that were identified as a result of literature review were around: a) lacking AED prevalence data in Australia, both at the population and among specific subgroups of the population such as youth; b) lacking sales data on AEDs in Australia; c) insufficient qualitative data on the social and cultural contexts of AED use amongst diverse groups such as those who consume a moderate number of AEDs per session and those who consume large amounts of AEDs; d) insufficient consultation with venue staff, police and emergency services personnel in order to understand the role that AED use plays for their service in relation to intoxication, side-effects and/or violence, what their training needs are in relation to treating AED-related harms, and how they currently collect and record information about AED use; e) whether AEDs are used by people high in risk-taking propensity and/or whether AED use causes increases in risk-taking behaviour; f) at what quantity of AEDs do side-effects rise appreciably; g) the role AED use plays on perceptions of intoxication and actual intoxication, particularly in relation to cognitive and motor performance and risk-taking (and at what quantities these occur), and h) whether policies implemented in Australia and elsewhere have been effective in reducing consumption and harms in relation to AED use.

### **Research Question 2: What do routine data collections tell us about the harms from mixing alcohol and energy drinks? What don't they tell us? Can we determine the effects on the health system?**

Most of the harms identified in relation to AEDs are self-reported by participants in surveys, with little data available on harms resulting from AEDs recorded through police, hospital, ambulance and coronial data. One of the reasons that these data are not more readily reported is because information on alcohol use, and particularly information on energy drinks, is often not well collected by emergency services as part of routine data collection. Unfortunately, there is very little data available from emergency services on AED use in NSW. The only data we were able to access were calls to the NSW State-Wide Poisons Information Centre (NSWPIC) and presentations to NSW emergency departments. Analysis of NSWPIC data from 1<sup>st</sup> January 2004 to 9<sup>th</sup> November 2012 was undertaken

alongside a retrospective analysis of records from the emergency departments of 59 hospitals in NSW from 1<sup>st</sup> January 2007 to 30<sup>th</sup> November 2012.

Thirty-nine poison centre calls related to AED use were recorded between 2004 and 2012, which represented 0.006% of all unique exposure-related calls to the NSWPIC. There were 657 presentations related to AED use between 2007 and 2012 across 59 EDs in NSW, representing 0.00006% of all presentations in the period. Poison centre calls peaked in 2008 and have remained relatively steady since then, with five or six per year. Emergency department presentations increased sharply from 2007 to 2009, but have remained relatively stable since that time, with around 120-140 presentations per year. The only international figures this data can be compared to is the US Drug Abuse Warning Network (DAWN), which reported 2,612 AED presentations in 2011 (as opposed to 145 in New South Wales in 2011); however, the US has a much larger population and the DAWN report incorporates data from emergency departments across the US and it is not clear from DAWN data what proportion of emergency department presentations is represented by AED use. While AED presentations to NSW EDs have been relatively stable over the past few years, US presentations are increasing, and as such further monitoring is required to ascertain whether these stable trends are maintained in NSW.

Broadly, the NSWPIC and emergency department data were consistent, providing a good understanding of the stability of trends (with calls and presentations peaking in 2007-2009 and remaining stable since that time). The number of calls relating to AED use was split evenly by gender in both the poison centre calls and emergency department presentations, which is somewhat surprising given that international literature and our current survey findings indicate that males use AEDs at higher rates and quantities than females. Most of the poison centre calls and emergency department presentations involved adolescents and young adults, consistent with international literature and our current survey findings about who is using AEDs. Over two thirds of poison centre calls involved the co-ingestion of AEDs with other substances, most commonly stimulants. On the other hand, only one sixth of AED presentations to EDs involved the co-ingestion of illicit drugs. Given that our survey findings revealed approximately 10% of AED consumers typically use ecstasy and cannabis with AEDs and 4% typically combine methamphetamine and cocaine with AEDs, it would appear that those combining illicit stimulants with AEDs are slightly over-represented in emergency department presentations and significantly over-represented in NSWPIC calls.

The primary symptoms reported in the context of poison centre calls included agitation, tremors, tachycardia, arrhythmias, nausea and vomiting. This was consistent with side effects experienced by AED users presenting to the emergency department, which included nausea, vomiting, palpitations, chest pain/tightness, tachycardia and anxiety. These symptoms are also broadly consistent with literature derived from self-report surveys, which include reports of vomiting, nausea, heart palpitations, racing heart, tachycardia and anxiety; however, other common symptoms reported in the literature, such as serious hangover and insomnia/difficulty sleeping, were not identified in NSWPIC calls and emergency department data, most likely because such issues are unlikely to lead to presentations to acute services.

The majority of poison centre calls resulted in emergency department presentations (31 of 39), but the majority of the emergency department presentations did not result in longer-term hospital admission, indicating that AED presentations resolve fairly quickly. However, it is important to note that of the approximate 50 presentations that did result in hospital admission, six of these resulted in admissions to the critical care ward (of which three had co-consumed illicit drugs with AEDs).

At present there is very little secondary data that can be sourced in NSW to paint a comprehensive picture of the nature of harms from AED use. What data were available reveals that there have been very low numbers of AED-related calls to NSWPIC and NSW emergency departments over the past nine years, suggesting that AED use is not placing a significant burden on acute emergency services. However, these numbers are likely to represent an underestimation of the harms associated with AED use due to poor recording of alcohol and energy drinks in routine data collection systems. It does appear that AED use is resulting in some health-related harms and these harms have increased over time. It will be important to regularly monitor these trends to ensure they don't increase substantially as is occurring in other countries such as the US, and it is important to ensure that data is collected in the most accurate way to ensure that harms from AED use are not going unrecorded. In particular, routine collection of AED-related presentations through ambulance services is likely to be important as paramedics in Melbourne have reported that they often treat AED users at festivals and around licensed venues without transporting them to emergency departments (132).

### **Research Question 3: How widespread is the practice of mixing alcohol and energy drinks amongst the NSW population?**

Our web and street survey deliberately targeted people most likely to consume AEDs – that is young people who currently consume alcohol and tend to frequent licensed venues. It is important to note that levels of alcohol consumption in this sample were significantly higher than levels of alcohol consumption among people of similar age in general population samples such as the National Drug Strategy Household Survey (1). This is most likely an outcome of our targeted sampling towards those who are likely to go out and consume alcohol in the night-time economy.

In both the web and street surveys, 38% of respondents reported having consumed an AED in the past 12 months. These prevalence rates are lower than international data which tend to report similar numbers, but in a shorter time frame (i.e. last month, not last twelve months). In addition, despite similar recruitment methods, a predominantly Tasmanian community sample ascertained by Peacock and colleagues (128) found that nearly 50% had consumed an AED in the past six months, again, a shorter time frame. Without more data available from other states of Australia it is difficult to compare whether use in NSW is significantly lower than the rest of the country or whether Tasmania is disproportionately high. Of those interviewed during the street intercept study, 10% had consumed an AED on the current night out (although in our recent POINTED study, 16% of NSW residents had consumed an AED on the current night out). This is consistent with the one US portal study identified, in which 13% of patrons had consumed an AED on the current night out (127).

### **What population groups mix alcohol with energy drinks?**

Consistent with US literature, findings from both surveys revealed that males were more likely to be AED users, and consumed significantly greater amounts of AEDs than females. Also consistent with international literature, a larger proportion of participants aged 18-25 reported having consumed AEDs than other age groups (47.7% of this age group in the web-survey and 41% in the street survey); however, there was little difference in quantity of AED use by adult age groups. Other factors that predicted use of AEDs were being single or casually dating (as opposed to being in a steady relationship) and being a tertiary student. Participants who earned between \$20,000 and \$35,000 were more likely to consume AEDs than other groups, though this finding is likely to reflect the significant student population in this income bracket.

Of some concern was the high rate of AED use reported by 16-17 year olds in this study. Web-survey participants in this age group reported consuming an average of 2.4 EDs in a typical AED session (consistent with other groups) but street survey participants of this age group reported 5.4 EDs per AED session, which was almost two EDs more than older age groups. In addition, 16-17 year olds in the street survey reported the highest number of EDs in a maximum AED session (6.5 EDs) and the highest alcohol in AED sessions (both typical and maximum sessions with 10.6 drinks and 13.9 drinks respectively). Further, in both surveys, 16-17 year olds reported the highest percentage of their alcoholic drinks in a typical AED session were AEDs (37.0% in the web-survey and 51.8% in the street survey). Of additional note, 16-17 year olds in the web-survey reported the highest prevalence of unmixed ED use (69.6% of all 16-17 year olds). When considering this finding it is important to bear in mind a number of things. Firstly, the sample of 16-17 years recruited in this study was small (comprising 2.4% of the web-survey sample and 3.4% of the street sample). Secondly, the type of 16-17 year olds captured in this survey (i.e., those that responded to an AED survey via social networking sites and those on the street late at night) may be a 'riskier' demographic of young people. It is also likely that the majority of AED's consumed by this age group were hand mixed outside of licensed venues due to licensing restrictions, potentially reducing the accuracy of standard drink estimates and skewing results. However, given the paucity of international research investigating AED use among people under the age of 18 we have little to compare our findings to and it is essential that more research on ED and AED use is undertaken with young people, particularly given that over a third of emergency department presentations as a result of AED use involved people under the age of 19.

### **What are the characteristics of use (i.e., When and where does it occur? How much is drunk? In what proportions? How often? Why?)**

Participants recruited through the web-survey reported consuming AEDs relatively infrequently (monthly or less), while half of street survey participants reported consuming AEDs monthly or more, suggesting that people frequenting venues are more likely to consume AEDs regularly. Street survey participants also reported higher levels of AED use, averaging 3.6 EDs (peaking between 1-2am) and 8.4 alcoholic drinks during AED sessions, compared with web-survey participants consuming 3.0 EDs and 6.0 alcoholic drinks per AED session. This is broadly consistent with international literature, and

Peacock et al.'s predominantly Tasmanian sample (128), which also suggested that young people tend to combine AEDs monthly or slightly more often and consume approximately 2-3 EDs per session and 7 alcoholic drinks.

Also consistent with international literature, the majority (85.2%) of AED consumers preferred hand-mix spirits with energy drinks rather than purchasing pre-mixed AEDs. Consumption contexts for AED consumption differed substantially from those of alcohol alone. AEDs were consumed most commonly in licensed venues, followed by private parties and live music festivals, again, in keeping with findings from the broader literature; whereas alcohol only users reported frequent consumption in these contexts in addition to at home alone or with meals. Many participants linked their AED consumption to specific environments. One of the most commonly reported reasons for not consuming AEDs was that participants were no longer attending nightlife venues as frequently, indicating that many participants view AED use as a behaviour specific to that environment and specific to a certain age.

The most frequently reported motivations for AED use were specific to participant's desires for energy/endurance, compensating for lack of sleep, and favouring the taste. Price and availability were also strong motivations. Alternately, motivations identified in the literature, such as increased intoxication or facilitating a desired intoxication and mimicking the effect of illicit stimulants were relatively infrequent.

#### **What are the health and social harms experienced from mixing alcohol and energy drinks? At what amount of energy drink and what amount of alcohol do these effects occur?**

The most commonly reported side effects experienced by AED users during sessions of AED use were racing heart/heart palpitations, insomnia, energy fluctuations and nausea. These side effects increased with increasing AED dose, peaking in prevalence at five AEDs. Racing heart was consistently the most commonly reported side effect at all consumption levels, increasing from 43% after 1 AED to 70% after 5 AEDs. However, at higher consumption levels, other side effects such as slurred speech, increased rate of speech, dizziness and decreased coordination became more common. These side-effects are consistent with the literature, but provide new information about how side-effects change with increasing dose of AEDs.

The most commonly reported 'after' effects (in the days following) of AED use were visual disturbances, nausea and fatigue. These side effects increased with increasing AED dose, peaking in prevalence between four and six AEDs. Visual disturbances were the most commonly reported 'after' effect of AED use at all consumption levels, but at five AEDs and above, side-effects such as nausea and fatigue were replaced with side-effects such as breathing difficulties, gastrointestinal issues, racing heart and heart palpitations. Aside from visual disturbances, these side-effects are consistent with the literature; however, do show that with increasing number of AEDs, symptoms become more serious, and differ from those typically associated with 'alcohol only' consumption.

People who had consumed AEDs in the past 12 months consumed significantly more alcohol than people who had not used AEDs (but had consumed alcohol) in the past 12 months. In addition, AED users in the street intercept study had a higher BAC at time of interview than those only consuming

alcohol (.066% versus .051%). AED users also consumed more illicit substances in the past 12 months than non-AED users, and a higher proportion of AED users reported involvement in aggressive incidents in the past 12 months (relative to non-AED users). This is consistent with international literature. Among AED users, those who reported mixing greater than two standard energy drinks in a typical AED session reported a significantly higher number of risk taking behaviours than those who consumed two or less EDs (5.8 risk-taking events versus 3.2).

However, within groups analyses revealed that AED consumers consumed more alcohol during typical 'alcohol only' sessions than during typical AED sessions, and they consumed illicit drugs more frequently during 'alcohol only' sessions than during AED sessions. This is an important contribution to the literature which has reported mixed findings in relation this point previously. Our study indicates that AEDs do not necessarily facilitate risk-taking, increased alcohol or illicit drug consumption or other harmful behaviours, but that AED users are a riskier group of people for whom a holistic targeted intervention is likely to be required.

#### **Does use differ between metropolitan, regional and rural communities?**

Findings from the web-survey suggested that Sydney residents were less likely to consume AEDs than residents in other geographical locations; however, when talking to those on the street, rates of AED use were consistent across nightlife locations in Sydney, Newcastle and Orange. Over 99% of the web-survey sample lived in areas deemed accessible or highly accessible according to ARIA classifications (Accessibility/Remoteness Index of Australia - 8), meaning the sample living in rural or remote communities was too small to assess differences in AED use in these areas.

#### **Research Question 4: Does AED use cause an underestimation of perceived intoxication? If present, are these effects dose-dependent?**

Findings from the experimental study revealed that participants had a lower BAC when consuming a moderate alcohol dose (~.05% BAC) with one, two or three standard EDs relative to without EDs. BACs were also typically lower after consuming the high alcohol dose (~.08% BAC) with EDs relative to alone, but only when the alcohol dose was consumed with 2 or 3 EDs. There was evidence that the volume of ED influenced BAC, with lower BAC recorded when three standard EDs were co-ingested with alcohol relative to one or two standard EDs. However, this effect was typically only evident when a moderate alcohol dose was consumed; there was limited evidence that BAC differed after a high alcohol dose according to the volume of EDs consumed.

After controlling for differences in BAC across the ED doses, there was no significant difference in estimation of intoxication when AED was consumed relative to alcohol. These results do not necessarily mean that participants accurately estimated their intoxication after consuming AEDs or even alcohol; rather, their perception of intoxication did not differ depending on whether alcohol was co-ingested with EDs. Previous research has shown higher BACs are recorded after consuming alcohol with an artificially sweetened mixer relative to a naturally sweetened mixer (164, 214), potentially because the body treats the latter similar to a food, resulting in slower gastric emptying and alcohol absorption. In the present study, the active ED contained approximately 27g sugar per 250mL,

as well as other active ingredients (e.g., 80mg caffeine, 1000mg taurine), while the placebo ED had no active ingredients (i.e., 0g sugar, 0mg caffeine, 0mg taurine). Thus, it may be that gastric emptying and alcohol absorption is impacted by the primary ED ingredients.

In regards to estimation of ED intake, participants were good at judging their ED intake up until the recommended daily intake threshold (i.e., two standard EDs), but they tended to underestimate their ED intake when consuming in excess of these guidelines (i.e., three standard EDs). When we controlled for ED-differences in BAC for the moderate and high alcohol group, we found that participants could not differentiate between the different ED doses when they had consumed a moderate alcohol dose. While they could detect the difference between a moderate ED dose and a low ED or no ED consumption after a high alcohol dose, they could not distinguish the difference between a high ED dose compared to moderate, low, or no ED consumption. These results suggest that alcohol consumption may impact on the ability to accurately detect the amount of ED consumed, with participants particularly poor at detecting a high ED dose which exceeds the recommended daily intake guidelines. This was the first study to look at perceived ED intake following alcohol consumption; replication of these results in future research is required before definitive conclusions can be drawn regarding consumers' accuracy in detecting ED intake. However, these results suggest that consumers in the night-time economy may have a reduced ability to detect and monitor their ED intake if there is no visible indication of the servings consumed.

#### **Does AED use cause an increase or decrease in actual intoxication outcomes via impairment on cognitive and motor performance outcomes? If present, are these effects dose-dependent?**

Findings from the experimental study demonstrated few effects of alcohol, EDs or AEDs on cognition, motor performance or driving performance. Results suggest that impairments from consuming alcohol, EDs, or consuming alcohol with EDs, was not apparent on the cognitive measures administered in the present study. In regards to motor performance, there were differential effects of alcohol and ED on gross motor performance when consumed at various doses for female participants, with better gross motor movement when those in the moderate or high alcohol group consumed no EDs compared to when they consumed a higher ED dose. Male participants' gross motor performance did not differ according to the amount of alcohol and ED consumed. There was no additional effect of AED relative to alcohol on fine motor movement after controlling for differences in BAC across the ED conditions. However, consuming alcohol with an ED dose that exceeded the recommended maximum daily intake (i.e., three standard EDs) improved balance compared to consuming the same dose of alcohol without EDs.

These results matched the majority of previous AED studies (74, 95, 157, 159), which have generally shown no significant difference in performance on cognitive and motor performance measures after consuming alcohol dose (0.6g/kg-1.0g/kg) with a low ED dose (approximately 250mL per 70kg person). However, caution should be exacted when interpreting the present results, particularly in the context of the real-life drinking experience, as analyses revealed that there was reduced power to reliably detect alcohol effects (and thus AED effects) on most measures of cognitive performance.

### **Does AED use increase or decrease blood pressure and heart rate? If present, are these effects dose-dependent?**

The results revealed that inflation in diastolic BP over time might be reduced when consuming alcohol with an ED dose that exceeds the recommended maximum daily intake (i.e., three standard EDs) relative to consuming alcohol without ED. However, this effect only occurred when a moderate alcohol dose was ingested. The results of the present study partially match previous research (202), which showed that caffeine reduced increases in diastolic BP seen after alcohol consumption. In contrast with previous research showing that caffeine reduces alcohol-induced increase in systolic BP (202), the present study revealed no treatment effects for systolic BP.

Decreases in HR seen when alcohol was consumed alone or with a low ED dose tended to disappear when consuming alcohol with an ED dose in excess of the recommended daily intake, with the combination of AED increasing HR, particularly when a high alcohol dose was consumed. These results are somewhat surprising, considering that alcohol consumption generally results in an increase in HR, with previous research showing no effect of caffeine on alcohol-induced changes in HR (202, 207). However, these studies have only examined the effect of one ED ingredient, not the whole beverage. In light of the inconsistency in the literature, future research replicating the HR results of the present study is required before definitive conclusions can be drawn.

Overall, these results suggest that there are temporary cardiovascular changes when AED is consumed relative to alcohol, depending on the dose of alcohol and ED. However, these results should be treated with caution when considering the implications for AED consumers, as it cannot be confirmed whether the changes in BP and HR translate into clinically significant and meaningful risk for consumers.

### **Does AED use cause an increase in behavioural risk-taking? If present, are these effects dose-dependent?**

There was no difference in driving risk-taking between groups in the experimental study depending on the quantity of alcohol, ED or AED consumed. These results match previous research by Peacock et al. (170), who found that there was no difference in risk-taking behaviour on the computerised Balloon Analogue Risk Task after consuming alcohol (.05g/kg) with 3.57mL/kg ED (approximately one standard ED per 70kg person) relative to when the same alcohol dose was consumed without ED (although risk-taking did increase following ED consumption (with or without alcohol) relative to placebo). However, these results should be interpreted in the context of a very low overall rate of risk-taking by all participants, regardless of alcohol or ED dose. Participants may have become hyper-vigilant when they thought they had consumed alcohol and consequently compensated for anticipated poor performance, particularly in light of the task reimbursement. The generalisability of these results to real-life risk-taking also needs to be considered, particularly in light of the various other external factors (e.g., peer influence) which might influence intoxicated behaviour.

### **Research Question 5: What is the maximum level of caffeine and other energy drink active ingredients in a standard alcoholic drink before adverse health effects occur? At what volume of energy drink and alcoholic drink do these adverse health effects occur?**

Survey findings demonstrated that some participants reported side-effects after one AED suggesting there is no definitive number of AEDs that can be consumed before health effects occur. However, survey findings also demonstrated that side effects experienced during sessions of AEDs were highest after consuming five AEDs and side effects reported in the days after AED use were highest after consuming between four and six AEDs. This was also the levels of AED use at which side effects (aside from racing heart which was consistent across consumption levels) changed to more serious symptoms, such as slurred and increased speech, dizziness, decreased coordination during sessions of AED use; and at which side effects (aside from vision difficulties, which were consistent across consumption levels) changed to more serious symptoms such as breathing difficulties, heart palpitations and gastrointestinal issues after sessions of AED use. In addition, survey findings revealed that self-reported risk taking behaviours, such as aggression (physical, verbal or sexual), driving while intoxicated, injuries to self or others, acting on a risky dare and experience of guilt post intoxication within the past 12 months, were highest after consumption of between 4 and 6 EDs. Given that ethical constraints prohibited us from administering participants more than three energy drinks and 0.65g/kg of alcohol, this might explain why findings in relation to increased risk-taking, cognitive impairment and poorer motor performance were absent in the experimental study.

#### **6.1 Study Limitations**

There are a number of study limitations that should be acknowledged. Unfortunately we were unable to quantify the burden of AED use on the healthcare system. There is very little data available from emergency services on AED use in New South Wales. In addition, the emergency department data that we were able to access was limited in the extent to which it could be analysed due to data custodian restrictions. The data available through NSWPIC and NSW emergency departments are likely to represent a underestimation of AED-related harms that require emergency department or poison centre assistance, because of data coding problems (i.e., health professionals may not ask about energy drink use or may not record energy drink use appropriately) and because patients may not disclose energy drink use (due to intoxication, because they cannot remember or because it does not occur to them) (132). In addition, it was not feasible to search for all possible cases of AED consumption in the emergency department records, and knowledge of energy drinks is likely to vary among health professionals.

A limitation of the emergency department and NSWPIC data was the limited data available regarding the quantity of alcohol and EDs consumed. Quantities were not able to be extracted from emergency department data and only reported for a minority of NSWPIC calls. Where reported in NSWPIC calls, the intake estimates were generally expressed as a range (e.g., 2 to 5 EDs), with the volume of the beverage rarely specified (i.e., 60mL, 250mL, or 500mL beverage). As such, average alcohol and ED intake for exposures reported to NSWPIC were not calculated. This absence of intake data could be

partly attributed to the nature of AED consumption, as simultaneous consumption of alcohol and EDs can be achieved by purchasing pre-mixed beverages and by manually mixing the two constituents together, thus making retrospective recall of intake challenging, particularly when consumers are experiencing negative side-effects as a consequence of their intake.

In regards to our survey component, although portal or patron interviews have substantial benefits in terms of investigating people who are patronising the night-time economy, a number of limitations should be noted. Firstly, such surveys are not generalisable to all people who attend licensed venues. Secondly, as potential participants were in the middle of a night out we could only collect information about their night until that point. Thirdly, interviews were conducted within a comparatively public environment, and therefore interviews were necessarily kept short, were not suitable for in-depth questions and were not of a highly personal nature. Finally, there was no way to ensure participants were telling the truth. As such, figures reported as prevalence and quantities are estimates only, and may be influenced by recall bias or participants withholding/exaggerating information.

Web survey data is less influenced by these factors due to the increased anonymity offered by the interface, but is more vulnerable to recall bias. As participants were being asked to recall session over the past 12 months, the potential exists for inaccuracies. Further, the sample is not representative of the NSW population because young AED users were deliberately and non-randomly targeted through recruitment, females were over-represented in the sample, and respondents were biased towards Newcastle and surrounding districts due to more successful recruitment methods in those areas. The length of the survey and the complexity of the questions also resulted in a lower overall response and completion rate compared to the street intercept approach. Further, the web survey was advertised as a study on energy drinks and alcohol – and this may have influenced those who use alcohol with energy drinks to answer the survey. However, prevalence rates for AED use remained highly consistent between survey samples.

In regards to the experimental study, it should be noted that while ED administration was double-blind, alcohol administration was single-blind, introducing possible experimenter bias. However, systematic and objective data collection procedures were implemented (e.g., computerised delivery of task instructions and subjective measures), and data processing and analysis was blind. In addition to this, perceived intoxication ratings were higher in the active alcohol conditions relative to the placebo alcohol conditions, introducing the possibility of alcohol expectancy effects. It should be noted that participants in the placebo alcohol group perceived some degree of intoxication, suggesting that the placebo alcohol manipulation was successful and that the participants in this group did believe they had consumed some alcohol.

Furthermore, it is standard practice to require abstinence from the treatment to ensure equivalent systemic drug levels on commencing the sessions. However, facilitated outcomes post-caffeine ingestion may be due to reversal of adverse caffeine withdrawal effects for regular consumers following abstinence. As session times varied for participants and caffeine abstinence was required for 8 hours prior, state of withdrawal may have differed across sessions and between participants, reducing the possibility of a systematic effect of caffeine withdrawal and reinstatement on outcomes.

However, future research should involve a single set time for sessions or a longer phase of caffeine abstinence to control for withdrawal reversal.

Finally, and most importantly, these measures were taken in an artificial environment, thus reducing the generalisability to real-life AED consumption.

## 6.2 Conclusions and Recommendations

The current study filled many of the research gaps that we identified in the literature review, particularly in relation to a) understanding the popularity of AED use among the population of interest (i.e., young NSW residents most likely to frequent the night-time economy), as well as patterns of use, quantity and frequencies of use, socio-demographics of users, use across geographical locations, benefits and side-effects of use; b) a preliminary understanding of the burden that AED use plays for emergency services; c) a better understanding that AED consumption does not necessarily cause increases in risk-taking behaviour, but that AED users are a riskier group of consumers for whom targeted intervention is warranted; d) an indication that AED side-effects and risk-taking behaviours peak between 4-6 AEDs, and e) knowledge that AED consumption of up to three EDs and 0.65g/kg of alcohol does not result in significant physiological impairment or influence cognitive and motor performance and risk-taking. However, the findings from our study also raise some additional questions, such as why does combining alcohol and EDs lead to reports of visual disturbances in the days following use?

It is important to note that levels of alcohol consumption in this sample are significantly higher than levels of alcohol consumption among people of similar age in general population samples such as the National Drug Strategy Household Survey (1). This is most likely an outcome of our targeted sampling towards those who are likely to go out and consume alcohol in the night-time economy, but does provide useful new information about levels of alcohol consumption among young people in this context, and is likely to be important for understanding increases in alcohol-related hospital presentations (3).

AEDs have exploded in popularity since the early 2000s, with sales increasing exponentially between 2001 and 2010 and still rising (although it is important to consider that ED sales are a small proportion of overall beverage sales). As a consequence, AED use appears relatively high among people who consume alcohol (with over a third of NSW residents in our surveys consuming them in the past 12 months). There have been increasing presentations to emergency departments and increasing calls to poison centres in the 2000s and it is important to consider that these increases may reflect the rising popularity of these drinks.

In general, AEDs are used around monthly and are used at levels above the recommended daily intake (greater than 2 EDs in a session). While most people do not use them excessively, a small subgroup of AED users consume these beverages in greater amounts. It does not appear that AED use is particularly high in one particular geographical location in NSW, though we did find slightly lower rates of AED use in Sydney in the web-survey. AEDs are most popular among males and young people,

but more research needs to be undertaken with those under the age of 18 given high levels of AED use identified among the small sample of young people in this study. AED use appears to decrease with age, similar to other sweet drinks such as 'alco-pops'. The literature review found that taste was the second most common reason for AED use, with up to 69% of consumers reporting taste as a motivation for use. The sweet, palatable taste of AEDs may be why they are particularly appealing for young people, in addition to their marketing, which is directed towards young people.

It does appear that AED users consume more alcohol and other drugs, and engage in more risk-taking behaviour than non-AED users. Indeed, Australian research has shown that AEDs are used by nearly three quarters of current ecstasy users (130). International research supports this finding and it has been suggested that energy drinks may attract a riskier, more impulsive consumer due to their marketing and public image, which is generally centred on associations with sport, masculinity, and risk-taking, and advertising messages that promise an intense psychoactive effect.

In conclusion, AEDs are popular in NSW, but the majority of people we surveyed had not used an AED in the past 12 months and had not consumed an AED during the current night out. In experimental settings, AED consumption does not appear to cause significant harms at doses of alcohol up to 0.08% BAC and 3 energy drinks, while available surveillance data suggest that AEDs do not place a significant burden on NSW emergency services. Young people interviewed for this study were exceeding daily recommended doses of 2 energy drinks on a typical night out (they were averaging between 3-3.5 energy drinks) and side-effects associated with use, including heart-palpitations, visual disturbances and risk-taking were most likely to occur after consuming 4-6 energy drinks. Findings from the survey suggest that AED users are a generally riskier group of consumers for whom a holistic targeted intervention is warranted. Taken together, these project findings reinforce the need to focus resources on addressing the broader issue of alcohol-related harms, particularly given the significant burden that such harms place on emergency services and the broader community.

We propose a number of recommendations in relation to health promotion, legislation, data monitoring and future research given that we found: i) high levels of AED use among adolescents, ii) the majority of AED users reported experiencing negative side-effects during and after consumption, iii) most AED consumers were exceeding recommended guidelines in relation to the maximum number of energy drinks that should be consumed daily, and iv) AED consumers are a group of people who engage in heavier alcohol and drug consumption and risk-taking behaviours than non-AED consumers.

### **Health promotion**

Survey and experimental findings revealed that AED users experienced side effects during sessions of use such as increased heart rate and heart palpitations, and visual disturbances and nausea in the days following AED consumption. Survey findings also revealed that experience of side-effects increased with increasing AED dose and that knowledge of side effects predicted reduced use of AEDs. As such, we recommend a range of activities to raise awareness of the potential side effects of AED use. These include:

- Media campaigns raising awareness about the harms of excessive alcohol consumption and the potential for energy drinks to contribute to this, targeted at the demographic of consumers using AEDs frequently at high levels – people aged 18-25 years, particularly young males and tertiary students. This might include television advertisements, billboards or other forms of media. A cost effective way of doing this would be to add energy drink information to an existing alcohol campaign rather than running a separate campaign.
- Given that AEDs are most commonly consumed in licensed venues, this is an ideal location for targeted advertising. We recommend that posters should be distributed to venues for placement in key locations such as toilets, containing information about the potential risks associated with combining alcohol and energy drinks.
- Use of AEDs was high among 16-17 year olds indicating that prevention and health promotion messages in schools is warranted. Adding AED component to existing drug education programs offered in schools might be an effective way of disseminating messages around potential harms of use.
- Information should be included on the packaging of EDs that allow consumers to purchase over the recommended daily intake (e.g., 1.25L bottles, 4 packs/6packs, etc.) warning of the 'high caffeine content' (similar to European and Canadian requirements).

## Legislation

Survey data revealed that price was a motivating factor for AED consumption and that consumption of more than two EDs significantly increased the likelihood of risk-taking behaviour. Furthermore, experimental data showed that consumers are not good at detecting their ED intake, particularly when consuming in excess of the current recommended maximum daily intake. As such, we recommend:

- Guidelines should be put in place to ensure the advertising, promotion or discounting of AEDs must have reasonable limits and controls to minimise the risk of rapid, excessive or irresponsible consumption of AEDs;
- Guidelines should be put in place to ensure that advertisements or promotions of AEDs should not involve the availability of non-standard sized drinks or the availability of AEDs in receptacles that encourage rapid drinking.

## Data Monitoring

Due to the limited Australian information available on AED use identified through the literature review and our scoping of data across health and administrative systems in NSW, we recommend:

- Questions relating to AED should be added to existing general population surveys (such as the National Drug Strategy Household Survey) so that trends can be monitored (relatively inexpensively) over time;
- Questions relating to AED should be added to existing surveys accessing high risk subpopulations such as youth (such as the Australian School Students Alcohol and Drug

Survey) and illicit drug users (such as the Ecstasy and Related Drugs Reporting System and the Illicit Drugs Reporting System) so trends can be monitored over time;

- Enhancement of additional coding of ambulance attendance data should be undertaken to enable identification of serious AED-related harms that occur without requiring transportation to hospital;
- Regular review of emergency department presentations data should be undertaken (utilising search terms for case notes) to monitor trends in presentations over time; and
- Regular monitoring of calls to the NSW Poisons Information Centre should be undertaken to identify trends in relation to AED harms over time.

## Research

While this study has filled some important gaps in our knowledge around the use of AEDs, particularly in NSW, there are still a number of avenues for investigation:

- We deliberately targeted the likely demographic of AED users in our sampling and it will be useful to also ascertain the prevalence of AED use in general population samples (including patterns of use, quantity and frequencies of use, socio-demographics of users, benefits and side-effects);
- Targeted research directed at specific sub-populations that were not significantly represented in this research such as illicit drug users and people under the age of 18 will be useful to understand how different groups of young people are using AEDs (including patterns of use, quantity and frequencies of use, socio-demographics of users, benefits and side effects);
- It may be useful to access sales data on EDs and pre-mixed AEDs to provide some insight as to their popularity in Australia;
- There have only been two small qualitative studies conducted in Australia with AED users, and as such there has been insufficient research exploring patterns of use and the social and cultural contexts of AED use amongst diverse samples including those who consume a moderate number of AEDs per session, and those who consume above the daily recommended number of EDs per session;
- Quantitative, qualitative and experimental research is needed to explore our finding in relation to visual disturbances, such as whether these effects are unique to AED use, the nature and severity of the visual disturbances, how they might impact driving and similar tasks and whether they occur after particular doses of AEDs.
- There has yet to be sufficient research conducted with venue staff, police and emergency services personnel, including observational research, interviews and analysis of ambulance and police data in order to understand a) the role that AED use plays for their service in relation to intoxication, side-effects and/or violence, b) what they know about AED-related harms and whether they need more training in treating AED-related harms; and c) how they currently collect and record information about AED use and whether there are more appropriate recording systems that can be implemented to more accurately gather information about AED use;

- Policy evaluation research is needed, such as research examining the impact of the Western Australian prohibition of sales of AEDs after midnight in inner-city venues;
- The results of the experimental research demonstrated that BAC tended to decrease with an increasing ED dose; however, this may be a consequence of higher sugar content in the active ED condition slowing the rate of alcohol absorption via longer gastric emptying. Further research is required to determine the independent effects of the primary ED ingredients on alcohol metabolism; and
- Participants in the experimental study were informed that they may receive a maximum of six alcoholic drinks per session which may explain low levels of behavioural risk-taking. Future research should examine the effects of alcohol expectancy, looking specifically at the impact of explicitly informing participants of the treatment administered. Such research would increase the ecological validity of outcomes, as it would be rare that AED consumers would be blind and unaware of the content of the beverage they were consuming.

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