THE IMPACT OF LOW TO MODERATE ALCOHOL CONSUMPTION ON DIFFERENT TYPES OF HUMAN PERFORMANCE

BY

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THESIS

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ABSTRACT

Despite extensive research into the effects of alcohol consumption, there is no clear understanding into the mechanisms underlying human information processing impairment. The acute consumption of alcohol was investigated to determine the implications for human information processing capabilities, and to identify the extent to which these implications were stage-specific. Further aims included the investigation and quantification of caffeine-induced antagonism of alcohol impairment. Moreover, the aforementioned relationships were investigated in morning versus evening conditions.

A test battery of six resource-specific tasks was utilised to measure visual perceptual, cognitive and sensory-motor performance, fashioned to return both simple and complex measures of each task. The tasks implemented were: visual perceptual performance (accommodation, visual detection, visual pattern recognition); cognition (memory recall- digit span); and motor output (modified Fitts‟ and a driving simulated line-tracking). Performance measures were recorded by the respective computer based tasks. Physiological variables measured included heart rate frequency, heart rate variability (RMSSD, High and Low Frequency Power) and body temperature. Saccade speed, saccade amplitude, pupil size and fixation duration were the oculomotor parameters measured. Three groups of participants (*alcohol*, *caffeine+alcohol* and *control*) n=36 were studied, split evenly between sexes in a mixed repeated/non-repeated measures design.

The *control* group performed all test batteries under no influence. The *alcohol* group performed test batteries one and two sober, and three and four under the influence of a 0.4 g/kg dose of alcohol. Group caffeine+*alcohol* conducted test battery one sober, two under the effect of caffeine only (4 mg/kg), and three and four under the influence of both caffeine and alcohol (0.4 g/kg). The third test battery demonstrated the effects of alcohol during the inclining phase of the blood alcohol curve, and the fourth represented the declining phase. Morning experimentation occurred between 10:00 - 12: 45 and 10:30 -13:15 with evening experimentation between 19:00 - 21:30 and 19:30 - 22:00.

Acute alcohol consumption at a dose of approximately 0.4 g/kg body weight effected an average peak breath alcohol concentration of 0.062 % and 0.059 % for the *alcohol* and *caffeine+alcohol* groups respectively. Task-related visual perceptual performance demonstrated significant decrements for simple reaction time, choice reaction time and error rate. Cognitive performance demonstrated no significant performance decrements, while motor performance indicated significant decrements in target accuracy only. Physiological parameters in response to alcohol consumption showed significantly decreased heart rate variability (RMSSD) in the modified Fitts‟ task only. A significant decrease in saccade amplitude in the memory task was the only change in oculomotor parameters. Prior caffeine consumption demonstrated limited antagonism to task-related alcohol impairment, significantly improving performance only in reduced error rate while reading. Caffeine consumption showed stimulating effects on physiological parameters, significantly increasing heart rate and heart rate variability when compared to alcohol alone.

The design of the tasks allows for comparison between complex and simple task performance, indicating resource utilisation and depletion. Complex tasks demonstrated higher resource utilisation, however with no statistical performance differences to simple tasks. Physiological parameters showed greater change in response to alcohol consumption, than did the performance measures. Alcohol consumption imposed significant changes in physiological and oculomotor parameters for cognitive tasks only, significantly increasing heart rate frequency and decreasing heart rate variability, skin temperature and saccade amplitude. Caffeine consumption showed no antagonism of alcohol-induced performance measures. Physiological measures showed that caffeine consumption imposed stimulating effects in only the neural reflex and memory tasks, significantly increasing heart rate frequency and heart rate variability. Prior caffeine consumption significantly decreased fixation duration in the memory task only.

The time of day at which alcohol was consumed demonstrated significant performance and physiological implications. Results indicated that morning consumption of alcohol imposes greater decrements in performance and larger fluctuations in physiological parameters than the decrements in evening experimental sessions.

It can be concluded that alcohol consumption at a dose of 0.4 g/kg affects all stages in the information processing chain. Task performance indicates that alcohol has a greater severity on the early stages of information processing. Conversely, under the influence of alcohol an increased task complexity induces greater effects on central stage information processing. In addition, caffeine consumption at a dose of 4 mg/kg prior to alcohol does not antagonise the alcohol-induced performance decrements.

Key Words: alcohol, visual perception, cognition, motor output, human resource utilisation, caffeine antagonism.

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CHAPTER I

INTRODUCTION

BACKGROUND TO THE STUDY

In South Africa, as in many other countries, alcohol is responsible for a considerable burden of death, disease and injury. Parry, Plüddemann, Steyn, Norman and Laubscher (2005) contend that the per capita annual alcohol consumption amongst drinkers in South African is greater than 16.1 litres. This gives South Africa one of the highest levels of alcohol consumption per drinker anywhere in the world (Rehm, Room, Monteiro, Gmel, Graham, Rehn, Sempos and Frick, 2004). Alcohol–related harm to health is not limited to drinkers but also affects organisations, families, bystanders and the broader community. Rehm & Parry (2009) state that in the year 2000, alcohol–related harm in South Africa accounted for 7.1% of all deaths and 7.0% of disability-adjusted life years lost, resulting in 1.1 million life years lost in that year.

It is well known that alcohol‟s pharmacological capacity as a central nervous system depressant (down regulator) has the ability to alter fine and gross motor control, decrease arousal levels and cognitive performance and increase reaction/response time, as well as to increase the perceived impairment of cognitive and motor performance (Schweizer, Vogel-sprott, Dixon and Jolicoeur, 2005). In addition, studies have contended that alcohol increases heart rate responses and has been shown to affect an individual‟s motivation levels. These effects may translate into many work environments with serious implications for safety and may cause detrimental performance effects. It is estimated that alcohol abuse costs South African companies R 20 billion each year, attributable to lost productivity, absenteeism, poor performance and tardiness (Parry, 2011).

The effects of alcohol and the accompanying impaired responses of acute and chronic intoxication have been the subject of many international and national studies over the last two decades. Studies have focused primarily on the effects of alcohol on perceptual and motor responses, with a lesser focus on cognitive impairments. Further, these studies investigated relatively low blood alcohol concentrations, with few investigating the effects of varying blood

alcohol levels. A majority of alcohol studies have relied on surveys and police road–side statistics to gain insight into intoxication levels (Rosman, Ferrante, & Marom, 2001; Keall, Frith, & Patterson, 2004; Mann *et al*., 2010).

More recent literature (Schweizer *et al*., 2005) suggests that there is a greater effect on the central stage of the information processing stream (cognitive functions) than on the last stage, motor output. The authors conclude that the central stage of processing is more sensitive to the impairing effects of alcohol than are the motor processes. Research in which an individual is required to perform two tasks in rapid succession (i.e. process two sets of information) indicates that moderate doses of alcohol diminish performance of the secondary task (Schweizer *et al*., 2005). This research on dual–task performance indicates that information processing is impaired by alcohol. However, it does not identify the stage of the cycle at which impairment occurs.

Research indicates that a temporal factor or circadian factor (time of day) also affects the severity of impairment (Wasielewski & Holloway, 2001). Studies indicate that the time of day at which the experimental session takes place, will affect the level of intoxication: this theory was established and supported in early alcohol literature (Jones, 1974; Maisto, Connors and Vuchinich, 1978). Recent literature contends that caffeine has the ability to antagonise the effect of alcohol impairment (Moskowitz & Burns, 1981; Hasenfratz, Bunge, Dal Prá, & Bättig, 1993; Liguori & Robinson, 2001). That caffeine antagonises the impairing effects of alcohol has been attributed to caffeine"s ability to reduce the rate of alcohol absorption. Furthermore, it is said that caffeine acts as a central nervous system stimulant, increasing heart rate and arousal levels.

STATEMENT OF THE PROBLEM

The deleterious effects of alcohol pose many short and long term problems, not only in terms of health but also in terms of safety and performance. The impairing effects of alcohol extend to areas beyond drunk–driving and workplace performance: alcohol abuse also encourages crime and violence– thereby affecting communities, homes and families.

A further issue pertaining to alcohol is that of the legal limit for driving under the influence of alcohol. Government has imposed a limit of 0.05% blood alcohol concentration as the legal limit for drunken driving. For any blood alcohol concentration in excess of this criterion the driver would be classified as unable to drive safely without being impaired by the effects of alcohol. With the majority of alcohol studies focusing on elementary issues such as motor output and with little focus on perceptual and cognitive tasks, there is uncertainty as to what stages of the information processing stream are affected by alcohol and to what degree. Furthermore, there is uncertainty as to what functional resources at stage specific levels of information processing are affected, limiting performance. By studying alcohol and its deleterious effects, at low to moderate doses, clarification of the impairments at a perceptual, cognitive and motor level can be made - allowing for a possible revision of the legal limit based on scientific evidence.

With the current social culture that exists in South Africa, it is of great importance to understand how alcohol affects work-related performance, in terms of immediate performance and performance the following day. This will provide valuable information regarding what aspects of information processing are affected, the extent of these effects and what the associated dangers of these impairments are. Understanding these effects will provide greater insight into the inherent dangers that accompany alcohol intoxication, thereby optimising worker performance and increasing worker safety on both the individual and collective levels.

AIMS AND OBJECTIVES

The aim of this study is to determine how alcohol affects the various elements of the human information processing system. There is great practical value in ascertaining whether and to what extent alcohol has a deleterious effect on cognitive processing in work–related tasks. Conducting experimentation at two varying complexities, this study looks to determine how attentional resources are allocated while under the influence of alcohol; allowing the researcher to ascertain whether the effects of alcohol consumption are isolated to one specific stage in information processing or if information processing is affected in its entirety. This study aims to investigate the alcohol-caffeine interaction and to ascertain if caffeine can

deter the debilitating effects of alcohol at these blood alcohol concentrations. By studying the action of caffeine antagonism on alcohol-related performance, this study aims to determine whether a central nervous system stimulant can deter the debilitating effects of alcohol. This will provide great practical application in helping improve worker performance and reducing the number of accidents and fatalities, by providing understanding of the effects of alcohol on human information processing performance. Lastly, the investigation of day versus night alcohol ingestion will provide information on the circadian effects of alcohol ingestion.

RESEARCH HYPOTHESES

The hypothesis proposed in this thesis is that low to moderate levels of alcohol consumption will affect an individual‟s information processing stream, which has an impact upon perception and cognition as well as motor output. Further, it is hypothesised that a difference in the severity of effects will be observed in morning versus evening alcohol consumption due to the impact of circadian rhythm. Additionally, it is theorised that the introduction of a central nervous system stimulant – in the form of caffeine – will allow the observation of interference in performance compared to that in the alcohol-only consumption conditions.

The statistical hypotheses proposed are that the results obtained from the alcohol and non-alcohol conditions will be significantly different from each other in terms of perceptual, cognitive and motor responses. In addition, the results obtained from the morning conditions will be significantly different from those of the evening conditions. Furthermore, the perceptual, cognitive and motor response results obtained from conditions with alcohol and caffeine will be significantly different to conditions with only alcohol.

CHAPTER II

REVIEW OF LITERATURE

INTRODUCTION

To comprehend issues that deal with the brain and more specifically how the brain processes information requires a broad understanding of the anatomy as well as each structure and function of the brain. For this purpose, this chapter seeks to describe the functioning of the brain and how the brain processes information. Thereafter, an explanation of how alcohol affects the human body will be introduced, followed by a review of what is already established regarding the effects of alcohol ingestion on information processing and bodily functions. Following this, circadian rhythm and alcohol related circadian changes will be discussed.

FUNCTIONING OF THE BRAIN

Cognition

The scientific term, cognition, describes the ability to processes information, change preferences and apply knowledge to everyday tasks (Matlin, 2008). Further, the ability to cognate has been described as natural and unnatural, implicit and explicit as well as conscious and unconscious (Matlin, 2008). Every action an individual executes requires some level of cognitive activity and mental processing: however, the degree to which this cognitive activity is required is underpinned by the task at hand. Wickens (2002) contends that the speed and accuracy at which cognitive processing occurs is dependent on the cognitive resources available for utilisation. Further, this directly relates to the amount of cognitive activity required and the type of task being conducted - rule-based or skill-based.

Skill-based tasks are automatic behaviours that are effortless in nature, require little feedback and pertain to basic motor performance of the body (Rasmussen, 1986). Conversely, rule-based tasks are conscious, explicit behaviours that require a great deal of effort and considerable feedback (Rasmussen, 1986).

Cognition taxes four main functional resources that are required to process information: perception, memory, decision-making and response selection, and motor response (Wickens,

1984a). The order in which these cognitive resources are activated and utilised will be discussed in the Wickens human information processing model.

Human Information processing

Wickens (1984) describes information processing as a process whereby the cognitive brain perceives a stimulus or multiple stimuli and selects an appropriate response (outcome). Human information processing consists of several cognitive operations mediating the transformation of a stimulus into a response (Lorist & Snel, 1997). These outcomes are the consequence of complex mental operations that the brain performs on information perceived from the external environment.

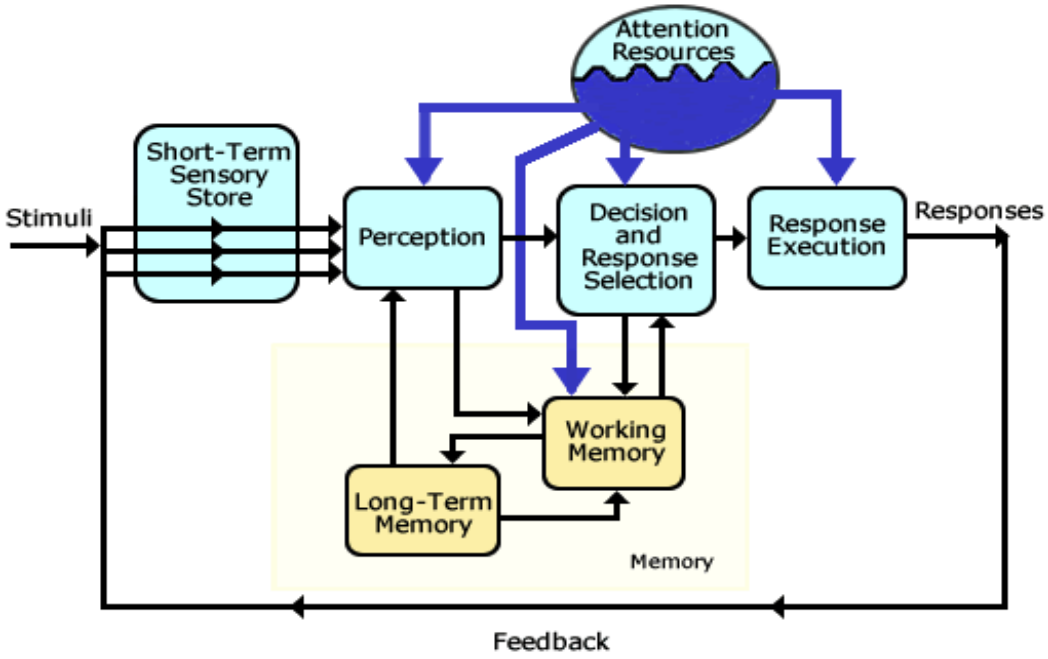

Figure 1: Wickens model of human information processing (adapted from Wickens, (1984a).

For information to be processed, most tasks that we as individuals are faced with follow a distinct sequence of processes which intervene between the presentation of a stimulus and initiation of a response. A typical sequence of such hypothetical stages (Figure 1) would be: 1) stimulus pre-processing at a sensory-perceptual level, followed by 2) stimulus categorization, wherein the stimulus item or information about the item is compared to other items stored in memory, followed by 3) response selection and organization, and 4) response

execution. Such paradigms usually contain the testable assumption that the successive stages of information processing are additive and non-overlapping (Tharp, Rundell, Lester, & Williams, 1974).

This sequence in detail is as follows; information is processed from the visual and auditory sensory receptors (eyes and ears) as well as from proprioceptive and kinaesthetic senses. The quality and quantity of the information that is registered has various limitations on each sensory system, and as a result may influence the processes that follow stimulus recognition (Wickens, 1984a). Once the information has been registered it reaches the level of the short term sensory store /working memory. Even though the stimulus has been terminated the short term sensory store prolongs the representation of the physical stimulus for a short period of time. In this model Wickens contends that the short term sensory store has three general characteristics: (1) it requires no conscious attention to prolong the stimulus - i.e. it is preattentive (2) It perceives most of the physical details of the stimulus - i.e. it is relatively veridical, and (3) it is rapidly decaying.

Once preservation of the stimulus has occurred, it is then processed by increasingly higher centres of the nervous system. The information then makes contact with a unique neural code that has been learned and stored in the brain (this code is said to be processed from previous encounters with similar stimuli). It is at this stage that Wickens describes the information as being perceived and it is assigned to a particular perceptual category. The link between perception and the unique learned neural code is displayed as the interaction between perception and the long term memory (Figure 1).

Perception is highly dependent on the complexity of the information presented. At a basic level the task may require a judgment as to whether a stimulus is present or not (Wickens, 1984b; Wickens, & Hollands, 2000). A greater level of complexity requires not only the detection of a stimulus, but also recognition, identification and categorisation of information. These sub-processes draw upon various resources that are present (e.g. attention and arousal). Therefore, as the complexity of the information increases, so the need for additional functional resources will increase (Egeth & Kahneman, 1975; Young & Stanton, 2002a,

2002b). Following the perception of the stimulus, the information enters the stage of decision and response selection (also commonly known as decision making).

Once information has been perceived it enters the next phase of processing, where the individual must decide what to do with the presented information. This stage, often referred to as response selection, involves the selection of the action that will be executed. A decision may be made immediately which will be followed by response execution, or in lieu, the individual may prefer to store the information in memory while deciding on an alternative response (Wickens, 1984a). If the decision is to commit the information to memory, it will then follow the path to working memory (Figure 1). A second decision may be made to retain the information in working memory (via rehearsal) or to attempt to permanently store the information in long term memory. Therefore, a great deal of choice is involved at this stage of information processing. Wickens (1984a) posits that the junction between decision making and response execution is a crucial connection in the information processing sequence, and may have positive and negative implications depending on the decision that is executed chosen.

With the decision to produce a response made, an added series of steps must be carried out to call up and release, with appropriate timing and force, the necessary muscular contractions to generate the desired action. This added phase is termed response execution. Wickens states that the decision to make the desired response is logically separate from its execution. Therefore response selection does not specifically equate to response execution, as selection infers the choice of producing an action, while execution is the physical movement produced as a result of the selection (Wickens, 1984a).

The final stage of the information processing, feedback, is the relay of information derived from the executed response. This closed loop provides information on the success or failure of the information processing cycle. If the response executed is to the individual‟s satisfaction then the cycle will end. However if the response is not satisfactory, the individual may repeat the entire process until satisfied. This feedback may take a variety of forms: visual, auditory, proprioceptive or tactile modalities.

Attention and resource allocation

Some of the first work conducted in the area of attention was carried out by Moray (1967), who proposed that attention was like the limited processing capacity of a general-purpose computer (Wickens, 1984a). Later, Egeth & Kahneman (1975) elaborated on this, stating that while attention had a limited capacity it was a flexible, sharable processing resource of limited availability. In order to process information and to obtain goal-directed behaviour, this processing chain requires a variety of resources. These resources are allocated according to the specific task demands and the relative complexity of the information set (Young & Stanton, 2002b). Egeth & Kahneman (1975) further proposed that each individual has a single undifferentiated pool of resources that are available to all tasks and all mental activities.

As task difficulty and task demands increase, physiological mechanisms would produce an increase in the supply of resources. However, if the task demanded excessive resources and the supply of resources could not meet the demand, then performance would falter or fail directly (Egeth & Kahneman, 1975; Wickens, 1984a). Two tasks that are performed together (a situation termed dual-task performance) are said to interfere with each other because both tasks will compete for the same resources, where previously each had exclusive access. Wickens (1984b) states that in this situation an underlying function – the performance-resource function - relates the quality of performance to the quantity of resources invested in the task.

Of noteworthy consideration is the premise that not all stages of the information processing stream require attention. The early stages of sensory analysis do not, whereas the later stages of perceptual analysis, cognition, response selection and response execution do require an input of attention (Egeth & Kahneman, 1975). These later stages require attention because the information processing at this stage is subject to interference. Egeth & Kahneman, (1975) argue that as the information approaches the response end, so the demand for attention increases. For the purposes of this study, resources may include (but are not limited to) structural, cognitive-energetical and functional resources (Navon & Gopher, 1979; Norman & Bobrow, 1975; Robert & Hockey, 1997; Wickens, 1984a). These resources could include (but are not limited to) those listed in Table I.

Table I: Information processing, stage specific resources

SENSORY	COGNITIVE	MOTOR
Ocular muscles	Decision making	Muscle recruitment
Visual perception	Visual perception	Force control
Visual recognition	Visual recognition	Precision control
Kinesthetic awareness	Memory	Motor programming
Haptic perception	Reasoning	Muscles
Situation awareness	Attention	

These early works on attention and resource allocation led to the formulation of a number of theories that further attempt to explain the concept of attention, how attention is allocated and how resources are utilised.

The capacity model of attention

The classic model of attention - theorised by Egeth & Kahneman (1975) - proposed a capacity model of attention as an alternative to earlier bottleneck and filter theories. This model suggested that there is a general limit to an individual‟s capacity to perform mental work. It assumes that this limited attention capacity may be allocated with considerable freedom among concurrent activities. Other researchers concur with a single resource view of attention, in that attention was perceived to consist of a pool containing a finite limit of resources (Wickens, 1984a). Further, Egeth & Kahneman (1975), suggested that attentional capacity was positively associated with physiological arousal, and that the ability to perform two separate concurrent activities depends upon the effective allocation of attention to each.

The capacity model was based on the premise that when task demands drained the pool, performance would deteriorate. In a dual-task paradigm, higher demands are placed on the information processing system (Wickens & Hollands, 2000). Therefore, the limited capacity of attention would result in the deterioration of performance in one or both tasks of the dual-task paradigm (van Duinen, Lorist, & Zijdewind, 2005). Contending researchers at this time were

of the opinion that performance may become impaired due to a lack of input by the participants or by unavailability of other processing resources (Norman & Bobrow, 1975)

Multiple resource theory

Wickens‟ multiple resource theory contrasted with the capacity resource model, in that this model illustrated several different capacities with resource properties – i.e. several pools of resources with the ability of being used at varying stages of information processing (Wickens, 1984b). Wickens argued that tasks would interfere more with one another if they were to share resources from a similar pool. Further, this model proposed that resources may be defined by three relatively simple dichotomous dimensions - two stage-defined resources (early versus late processes), two modality-defined dimensions (auditory versus visual encoding) and two resources defined by processing codes (spatial and verbal).

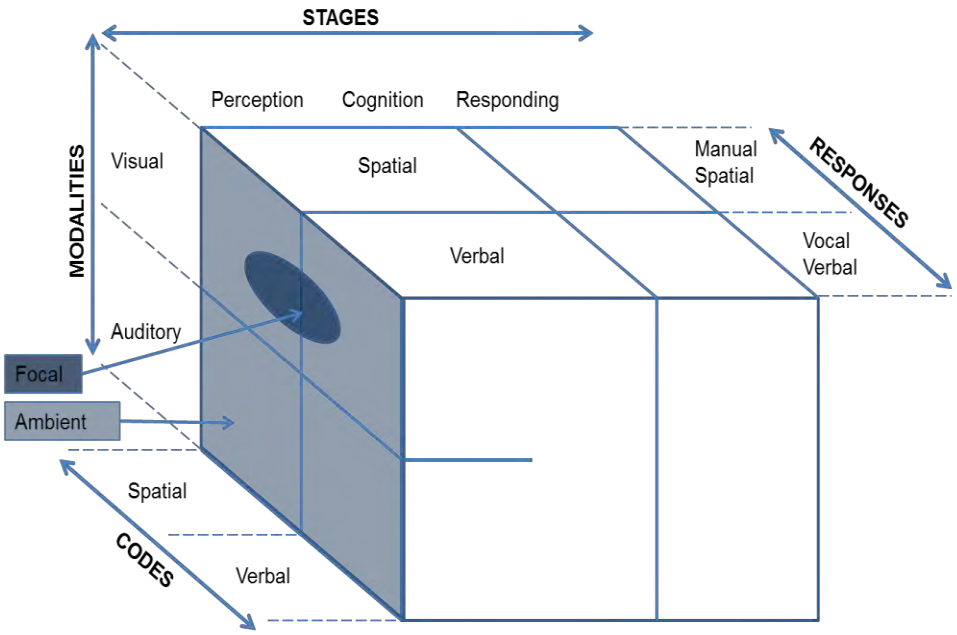

Figure 2: Wickens 4-D multiple resources model (adapted from Wickens, 2008).

Figure 2 presents the dimensional representation of multiple resources. This model proposes that to any extent that two tasks demand separate rather than homogenous resources on any three of the, three phenomena are to occur: (1) Time-sharing will be more efficient. (2) Changes in the difficulty of one task will be less likely to influence performance on the

secondary task. (3) The performance operating characteristic will demonstrate a higher level of efficiency (Wickens, 2008).

According to Wickens, (2008) the stages of processing dimension indicates that perceptual and cognitive tasks (e.g. working memory) use different resources from those underlying the selection and execution of action. The codes of processing dimension indicates that spatial activity uses different resources than verbal/linguistic activity, a dichotomy expressed in perception, working memory, and action (Wickens, 2008). Resources underlying spatial processing and left-hand control reside predominantly in the right brain hemisphere whereas resources underlying verbal processing, speech responses and right-hand control reside in the left (Wickens, 1984b).

Lastly the modalities dimension (nested within perception and not manifest within cognition or response) indicates that auditory perception uses different resources than visual perception. Therefore, two tasks running concurrently and taxing resources from the same modality (intramodal) will result in a decreased performance. Similarly, performance requiring bimodal resource allocation will be increased due to a decreased interference between tasks (Wickens, 1984b).

The fourth dimension nested within the visual resources was later added to this model. This dimension, termed visual channels, allowed for distinguishing between focal and ambient vision (Wickens, 2008). Focal vision, primarily foveal (but not exclusively), supports object recognition and, in particular, high acuity perception such as that involved in reading text and recognizing symbols. Ambient vision on the other hand is distributed across the entire visual field. This resource is responsible for the perception of orientation and movement, for tasks such as those supporting walking upright in targeted directions or lane keeping on the highway (Wickens, 2008).

Malleable attentional resources theory (MART)

Young & Stanton (2002a) posit that attentional resource theories make a common basic assumption about performance, that is, if demands exceed resource capacity, performance degrades. As stated in the original capacity model, Egeth & Kahneman (1975) argue that

attentional capacity closely correlated with physiological arousal. However, certain researchers are of the opinion that resource size may fluctuate with long-term changes in mood or age (Hasher & Zacks, 1979; Humphreys & Revelle, 1984) while others are of the firm opinion that the size of the resource pool is fixed (Wickens, 1984a).

The malleable attentional resource theory postulates that the limit on the specific resource pool may change depending on the task circumstances. The model hypothesizes that the size of attentional resource pool varies positively with mental work load. This criterion is however only true up to a finite limit, in that excessive reductions in mental work load shrink attentional capacity (resulting in performance decrements), and that this is independent of variations in arousal or effort (Young & Stanton, 2002a).

Young & Stanton (2002a) prove this theory in a driving-related study directed at automotive automation using a simulator task. The hypothesis was that mental work load would decrease as driving automation increased. The researchers observed that the attention ratio (ratio between the secondary task score and the amount of visual attention directed at the secondary task) decreased in line with the mental work load data from a secondary task. It was found that as automation increased, mental work load and attention ratio decreased. Therefore, when mental work load decreased, the allocation of attention to the secondary task became less efficient.

The researchers attributed this finding to two possible explanations: a) shrinkage of attentional resources or b) a change in strategy by the participants reflecting a speed-accuracy trade-off. However, because “the analysis of the secondary task error rates remained stable (approximately 5%) in all four conditions, it is unlikely that such a strategy change was occurring. Therefore, the researchers concluded that malleable attentional resource theory was the most likely explanation for these data” (Young & Stanton 2002a p19). Furthermore, the fact that driving performance did not improve with reductions in task demands, implies that all spare capacity was allocated to the secondary task. This experiment provides strong evidence for an association between task demands and attentional resource capacity.

ALCOHOL

Alcohol is known to impair functioning in a variety of domains, including behaviour, memory, and judgment (Bartholow, Pearson, Sher, Wieman, Fabiani & Gratton, 2003). Many of the findings regarding the effects of alcohol stem from the impairment of cognitive functioning. However, whether or not this effect is the result of global impairment of cognition, or from a specific impairment of central brain systems, is still unclear.

Alcohol use in South Africa

South Africans possess a culture where people enjoy their leisure time with an occasional drink. Further, it is a general belief that drinking is culturally acceptable and an integral part of the South African social culture. However, a substantial proportion of South Africans drink at levels that increase their risk of alcohol–related harm. A fair number of these South Africans will binge drink on weekends as well as weekdays and will carry the effects of heavy drinking into the following work day. An individual who consumes more than five (male) or four (female) drinks in two hours can be classified as a binge drinker (Parry, 2011). Studies have shown that acute alcohol intoxication may impair processes for a significant time after the blood alcohol concentration has diluted completely. Results indicate that attention is impaired for as long as 15 hours after blood alcohol concentration has reached zero. Psychomotor performance can also be affected as much as 3 hours post-recovery, while memory and cognition are still being affected the morning after alcohol ingestion (International center for alcohol polocies, 2003; Prat, Adan, & Sànchez-turet, 2008).

Additionally, there may be instances where individuals arrive at work under the influence of alcohol. In these situations the affected individuals will continue working while subject to the various impairments of alcohol. In turn, these impairments transfer into work and performance, resulting in absenteeism and decrements in performance (sub-standard performance, tardiness, or lost productivity) and an increased risk with regard to safety and accidents – this is especially true for individuals that operate heavy machinery and plant equipment. The risks associated with being intoxicated in the workplace may have serious consequences and have the potential to affect a large number of people beyond the drinker. The impairing effects of alcohol clearly extend into many branches of working life, and as a

result should be studied in order to ascertain the varying effects of alcohol on human information processing performance.

Acute effects of alcohol

The pharmacological effect of alcohol on the human body is a direct reflection of the amount of alcohol circulating in the blood, known as the blood alcohol concentration. This is largely dependent on the presence of food within the stomach, the rate at which the alcohol was consumed, the relative concentration of alcohol and the constitution of the individual consuming the alcohol (Hanson, Venturelli & Fleckenstein, 2008). Alcohol intoxication is associated with changes in subjective mood states and feelings of intoxication as well as impairments in psychomotor performance and cognitive processes such as memory, divided attention, and planning (Field, Wiers, Christiansen, Fillmore & Verster, 2010).

One of the most powerful effects of alcohol intoxication is to reduce the pace of brain activity (National Institute on Alcohol Abuse and Alcoholism, 2000). The presence of ethyl alcohol in the central nervous system interferes with the transmission of nerve impulses at synapses, inhibiting the flow of sodium ions across the cell membrane, causing difficulty in nerve firing (Fransson, Modig, Patel, Gomez, & Magnusson, 2010). Furthermore, this pace is affected in part by a decrease in the excitatory actions of the neurotransmitter, glutamate, at the N-Methyl-D-aspartate subtype of glutamate receptor. Alcohol also promotes the inhibitory actions of the neurotransmitter gamma-amino butyric acid at the gamma-amino butyric acid receptor. Increasing blood alcohol concentrations result in further deterioration of nerve impulse transmission. According to Fransson *et al*. (2010), substantial intoxication may lead to inhibition of voltage-gated calcium channels and can lengthen the conduction time at synapses and neuromuscular junctions. Furthermore, alcohol intoxication alters the production and functioning of other transmitters such as dopamine, serotonin and brain endorphins (Hanson *et al.,* 2008). These actions are among the reasons that alcohol is often thought of as a depressant (National Institute on Alcohol Abuse and Alcoholism, 2000).

The short-term impact of alcohol is to depress central nervous system functioning (Hanson *et al*., 2008). At low to moderate doses, disinhibition occurs; this is a reduction in conditioned reflexes due to the depression of the inhibitory centres of the brain. Moderate doses of

alcohol effect a slight increase in heart rate, dilation of peripheral blood vessels and moderately lower blood pressure. Further, Hanson *et al*. (2008) report that depression of the cerebellum, causing slurred speech and staggering gait are evident at moderate doses. In addition, alcohol at these levels is said to decrease an individual‟s ability to perform tasks that require vigilance and rapid decision making.

Central nervous system depression at high doses incapacitates the individual, causing difficulty in walking, talking and thinking. When large amounts of alcohol are consumed rapidly, severe depression of the brain system and motor control area of the brain occurs, providing incoordination, confusion, disorientation, stupor, anaesthesia, coma and even death (Hanson *et al*., 2008).

Although performance on most cognitive and psychomotor tasks is impaired at fairly high doses of alcohol, the dose of alcohol required to produce some degree of impairment varies for different psychological functions (Field *et al*., 2010). These authors argue that complex tasks are impaired at far lower breath alcohol concentrations compared to more straightforward tasks. Complex tasks such as divided attention are impaired at fairly low doses (blood alcohol concentration around 0.011%), whereas much higher doses of alcohol are required to produce a slowing in simple reaction time, approximately 0.08% blood alcohol concentration, (Field *et al*., 2010).

Research has confirmed that for the same dose of alcohol, females will become more impaired than males, for both acute and long term effects (Mumenthaler, Taylor, O‟Hara, and Yesavage, 1999). Further, for the same dose of alcohol, females will also display higher breath alcohol concentrations (Graham, Wilsnack, Dawson, and Vogeltanz, 1998). Reasons for this difference lie in the fact that females have proportionally more body fat and less body water than do males with the same body weight. Because alcohol is dispersed in body water, women reach higher peak BACs than men (Mumenthaler *et al*., 1999). Furthermore, females absorb and eliminate alcohol at a faster rate than do males, potentially impacting this higher blood alcohol concentration.

In review of alcohol related performance, Mumenthaler *et al*. (1999) states that when gender differences in blood alcohol concentrations are controlled statistically no overall gender

differences are detected for intoxicated performance. However, women recovered short-term memory functioning significantly more slowly than did men. More gender related differences are presented below in an extract from Mumenthaler *et al*. (1999)

Table II: Gender-related differences in response to alcohol (from Mumenthaler *et al*., 1999).

Study	*N* m	*N* w	Dose (g/kg)	BAC (%)	Tasks Tested	Difference	Remarks
Mulvihill et al. 1997	24	24	m 0.62 w 0.54	m 0.07 w 0.074	Reaction time	no	
Taylor et al. 1996	11	12	m 0.77 w 0.67	m 0.08 w 0.084	Flight simulator tasks	no	Performance change measured at acute intoxication and 8 hours later
Haut et al. 1989	22	22	0.80	Not reported	Word retrieval from long-term memory, cognitive decision tasks	yes	Greater performance deficits in women (responded significantly slower on all decision tasks)
Niaura et al. 1987	11	13	0.65	m 0.054 w 0.062	Divided attention, body sway, short-term memory, pursuit tracking	no yes	No overall gender differences in performance, but slower short-term memory recovery in women
Mills and Bisgrove 1983	12	12	0.37 0.76[a]	m 0.03 w 0.03 m 0.06 w 0.06	Divided attention, body sway	no yes	No gender differences at low alcohol dose, but women significantly more impaired on divided attention at high alcohol doses
Wait et al. 1982	20	20	1.25	Not reported	Eye-brain-hand coordination	no	
Burns and Moskowitz 1978	10	10	1.00	m 0.10 w 0.10	Information processing, hand steadiness, body sway, response latency	no	
Jones and Jones 1977	10	20	0.52	m 0.04 w 0.04	Immediate recall	yes	Women significantly more impaired on short-term memory
Jones and Jones 1976*a,b*	10	20	0.52	m 0.063 w 0.072	Immediate and delayed recall	yes	Women significantly more impaired on delayed recall, not on immediate recall.

BAC = blood alcohol concentration; g/kg = grams of alcohol per kilogram of body weight; *N* = number of subjects; m = men; w = women.
[a] with dose adjustments for different body fat percentage.
NOTE: These studies indicate that women show more impairment than men do on short-term cognitive tasks following alcohol consumption.

Impact of alcohol on information processing

The deleterious effects of alcohol on activities that require an individual to process information have been well researched (Goldberg, 1943; Carpenter, 1962; Fillmore & Van Selst, 2002), and it has been demonstrated that impairment occurs following alcohol ingestion (Koelega, 1995). The section to follow highlights research at a resource specific level and identifies how

alcohol affects each individual resource. Thereafter the contention of the various theories on impairment of information processing by alcohol is discussed.

From as early as 1926, information processing and the effects of alcohol on information processing have been a central topic in human performance. The works of Tharp *et al*. (1974) investigated the constraints of alcohol on information processing. These authors brought to light the possibilities that alcohol may constrain human information processing performance, suggesting that the drug affects a slowing in one or more stages of information processing (Figure 1). It was hypothesised that alcohol may cause an overlap between normally discrete stages, that it might alter the normal sequences of cognitive stages, or it might reduce the accuracy of performance by impairing the output of one or more stages. Yet even today in 2012, we have yet to find a satisfactory explanation for the disruption in performance due to alcohol.

Acute effects of alcohol on visual perceptual performance

Unlike the central stages of information processing, the early stages of information processing have been reviewed to a far lesser extent. These first stages of information processing are described as those that require the detection of visual, auditory and kinaesthetic stimuli (Koelega, 1995).

Tzambazis & Stough (2000) studied the effect of alcohol on inspection time and simple and complex reaction times in conjunction with cognitive ability tests (adult intelligence scale – revised) as representatives of early stage and total information processing. Inspection time (early stage) was found to be significantly longer in conditions involving alcohol ingestion in comparison to placebo conditions. Additionally, both simple and complex reaction times were longer when blood alcohol was 0.05%, compared to a blood alcohol concentration of zero. These findings on inspection time suggest that alcohol impairs early stage information processing involving processing speed.

In accordance with the above, Jaaskelainen, Pekkonen, Alho, Sinclair, Sillanaukee and Naatanen, (1995) investigated early stage information processing by examining mismatch negativity – a component of the auditory event-related potential – under low doses of alcohol

ingestion. These researchers contended that mismatch negativity suppression was markedly stronger when stimulus deviation was smaller, indicating that the detection of small deviations in stimuli while under the influence of alcohol is especially hampered resulting in a decrease in processing speed.

Similar results have been presented by Krull, Smith and Parsons, (1994), who examined simple reaction time tasks with two levels of stimulus intensity. In this study it was found that the presence of alcohol resulted in impaired stimulus detection, suggesting degradation in sensory-perceptual processes and degree of attentiveness.

Acute effects of alcohol on cognitive performance

A considerable number of studies have assessed alcohol-related cognitive performance through attention tasks and measures of response time, response accuracy and vigilance. The results obtained have been uniform, with the majority of researchers agreeing that, when task demand is high, such us under conditions of dual task performance, the impairment in performance significantly increases (Tzambazis & Stough, 2000; Fillmore & Van Selst, 2002; Schweizer, Vogel-sprott, Dixon, Jolicœur, 2005).

Tzambazis & Stough (2000) state that ingestion of alcohol increases the number of errors threefold on a reaction time task, and doubles the errors on a visual structuring task – a result supported by Bartl, Lager, and Domesle, (1996). Similar results have been found in simple visual and auditory reaction time tasks. The increase in reaction times and the higher percentage of errors may be linked to the existence of a facilitation of performance that precedes impairment (Tzambazis & Stough, 2000). These authors further contend that information processing may be impaired at the same time as motor functions are facilitated, resulting in premature reactions (false alarms) and the facilitation of errors.

Schweizer, *et al*. (2005) conducted an investigation using a psychological refractory period paradigm to investigate the effects of an acute, moderate dose of alcohol on the ability to perform two tasks in rapid succession. The authors argue that an increase in reaction time due to diminishing stimulus onset-asynchrony indicates that the central stage of information

processing is significantly affected by alcohol consumption – more so than motor co-ordination and function.

Schweizer, *et al*. (2005) state “The fact that the pattern of reaction times implicates an alcohol-induced disruption of the central, rather than the motor stage, is important because it suggests that cognitive processes may be more sensitive to the impairing effect of moderate rising blood alcohol levels than are motor processes”. These authors later suggest that the over-additive effect of alcohol on reaction time (secondary task) could be associated with a pre-central (stimulus identification) effect in combination with the central stage effect. The above view is further supported by Levine, Kramer & Levine (1975) who found that low to moderate BAC levels deleteriously affect attention and information processing, as opposed to motor coordination.

Other areas of central processing that have received attention are those of learning and memory. Investigations into learning and memory have been centred upon word categorisation, word recall and recognition, creativity and cognitive-motor performance. It has been stated that word categorisation and word recognition – two tasks that assess complex cognitive processes – have been shown to be deleteriously affected by the ingestion of alcohol (Tzambazis & Stough, 2000). With reference to word categorisation, alcohol has been shown to cause a slowing in responses, which are also less accurate. Other research conducted (Maylor, Rabbitt and Kingstone, 1987) illustrates that alcohol has the ability to decrease performance in word categorisation tasks, but may improve or impair accurate semantic performance in tasks such as word recognition.

Further, alcohol-related cognitive ability studies (Tzambazis & Stough, 2000), confirm that alcohol administration resulted in impaired performance on perceptual organization, synthesis of thought, abstract thought, decision making and attention to detail. Conversely, short-term memory, visual memory, freedom from distractibility and anxiety as well as visuo-motor coordination have not shown impairment. These results are based on the revised adult intelligence scale tests which measure several performance subtests, including: picture completion, picture arrangement, block design, object assembly and digit symbol.

Certain memory tasks represent higher-order cognitive functioning. Studies have implemented memory tests to measure alcohol-related implicit and explicit aspects of memory (Lister, Gorenstein, Fisher-Flowers, Weingartner, and Eckardt, 1991). These researchers illustrated that alcohol impaired the ability to explicitly remember words, but did not impair memory on the same material when assessed implicitly. Tzambazis & Stough (2000) state that, based on a picture completion task, the ability to draw on long -term memory is reduced under conditions of alcohol ingestion.

Performance with regard to free recall of relevant cues was shown to increase with moderate doses of alcohol – a study conducted by Jubis (1986). It was explained that, as alcohol induced arousal, attention to high-priority task components was enhanced. In such cases, speed and accuracy were unaffected. In recent research conducted in the Department of Human Kinetics and Ergonomics, Rhodes University, Huysamen (2011) and Parker (2011) observed that a memory recall task (digit span) was sensitive to a change in complexity but not sensitive to a change in time of day. Parker (2011) demonstrated that alcohol consumption reduced the ability to correctly recall five- and seven- number sequences, with a lower percentage of correct responses in the seven- number sequences.

Acute effects of alcohol on motor performance

Motor performance while subjected to the effects of alcohol has been extensively studied in relation to driving performance (Ando, Iwata, Ishikawa, Dakeishi, & Murata, 2008; Elmenhorst *et al*., 2009; Fillmore, Blackburn, & Harrison, 2008; Harrison & Fillmore, 2011). There are however, few studies that have investigated motor effects in relation to alcohol consumption. The majority of alcohol studies have relied on posturography, hand tremor frequency and reaction times to establish motor performance in relation to alcohol consumption (Hiltunen, 1997; Ando, Iwata, Ishikawa, Dakeishi, & Murata, 2008; Brumback, Cao, & King, 2007).

While most statutory limits for driving are set at blood alcohol concentrations of 0.08% and higher, laboratory research on human subjects has indicated that blood alcohol concentrations as low as 0.05% significantly impair performance in certain motor tasks (Brumback *et al*., 2007). Tasks that have shown such effects include tracking tasks, tapping, reaction time tasks and posturography. Psychomotor tasks that are more cognitively

demanding in nature (cued go/no-go tasks and choice reaction time tasks) have also shown to be sensitive to alcohol levels below 0.05% (Fillmore, Marczinski & Bowman, 2005). Brumback *et al*. (2007) argue that the sensitivity to the impairing effects of alcohol is relative to the level of complexity of the psychomotor task - higher complexity inferring decreases in performance.

Fine motor control testing, by means of the pegboard test, indicated that alcohol consumption significantly slowed performance when compared to a non-drinking group (Brumback *et al*., 2007). In this same study Brumback *et al*. (2007), demonstrated that perceptual-motor programming speed (measured by DSST) was impaired by the ingestion of alcohol, with fewer correct scores obtained throughout all time points. In a task requiring object assembly Tzambazis & Stough (2000) found that alcohol impaired participants‟ visual motor coordination reducing the ability to produce the movements required to respond to an appropriate stimulus.

Investigations in regard to neuromotor functioning have revealed significant increases in postural sway and marked increases in reaction time and hand tremor following acute alcohol ingestion (Ando *et al*., 2008). Further, these authors reported a significant delay in visual reaction time following exposure to a 1 g/kg body weight dose of alcohol (Ando *et al*., 2008). This finding is supported by Elmenhorst *et al*. (2009), who demonstrated a significant increase in reaction time following acute alcohol intoxication.

Elmenhorst *et al*. (2009), who investigated driving performance while under the influence of alcohol, demonstrated significant increases in errors (lapses) within the reaction time task and a significantly decreased target deviation in an unstable tracking task, as measured by the root mean squared. In another driving related study, Fairclough & Graham (1999) reported a significant effect for lane crossing post alcohol ingestion. A significantly higher number of lane crossings were observed in the fully sleep- deprived and alcohol groups when compared with the partially sleep- deprived and control groups. Rupp, Acebo, Seifer & Carskadon (2007) reported significantly higher lane variability when participants were under the influence of alcohol compared to driving without alcohol consumption.

Fillmore, Blackburn, & Harrison (2008), in a driving-related alcohol study, found line crossing, steering rate, driving speed and stopping failures to increase significantly while under the influence of alcohol. Further, these increases translated into a driving profile characterized by greater deviation of lane position, increased line crossings, more failures to stop at red lights, faster, more abrupt steering manoeuvres, greater acceleration, and faster overall speed. From these finding it appears that alcohol consumption imposes a speed accuracy trade-off. According to Schmidt and Wrisberg (2008) the speed accuracy trade-off is the tendency of an individual to substitute accuracy for speed, or vice versa, in their movements depending on task demands.

Theories on impairment of information processing

Several interpretations of how alcohol impairs information processing have been proposed. These various theories are in contention, in that some researchers argue that one specific stage is responsible for the bottleneck in performance, whereas other researchers believe the breakdown in performance is due to multiple resource failure.

Studies confirm that the drug disrupts performance on a wide range of activities that require behavioural control and inhibition of responses (Fillmore & Van Selst, 2002). In early research conducted into alcohol and information processing, McCorkindale (1926) proposed that alcohol directly causes disinhibition by anaesthetizing particular brain areas that control or inhibit behaviour. This implies that inhibitory centres of the brain are particularly vulnerable to alcohol"s effects.

A theory proposed by Rohrbaugh, *et al*., (1988) suggests that early stage impairment by alcohol may be the cause of decreased performance. These authors suggest that a chain-like-reaction occurs through the information processing stream, starting at the early stages and progressing through to response execution, thereby affecting total information processing. Alternatively, research conducted in the field of visual spatial attention suggests that all stages of information processing are affected independently. Tzambazis & Stough (2000) posit that alcohol impairs performance only in tasks that place greater demands on visual spatial attention, causing a disruption in the ability to shift attention from one spatial aspect to the next. This higher order task switching is uncommon at the early stages of

information processing. Tzambazis & Stough (2000) state that this theory is supported by (Koelega, 1995), who asserted that most tasks assessing early information processing are less sensitive to the effects of alcohol.

More recently explanations have centred on cognitive constraints limiting performance. These accounts suggest that alcohol impairs the capacity for processing information. This notion is supported by several researchers (Josephs and Steele 1988; Fillmore, Van Selst, 2002; Schweizer, *et al*., 2005).

Schweizer *et al*. (2005) support the cognitive capacity limitation theory. The authors verify that when a dual task is performed in quick secession, performance on the second task is increasingly degraded as the temporal gap between task one and task two decreases. These authors assume that the carryover effect on task two is present because the central cognitive stage of processing must be completed before the second task can begin to be processed.

Steele and Josephs (1988) proposed a model relating to alcohol‟s influence on attentional processes. According to this attention-allocation model, alcohol intoxication restricts an individual‟s focus of attention to only the most prominent cues in the environment, such that all available cues are not fully processed. This suggests that alcohol impairs the capacity for processing information conveyed by cues that signal when responses are to be executed or inhibited. Furthermore, such accounts imply that the ability to inhibit a response is not essentially vulnerable to the effects of alcohol; rather, that alcohol impairs the capacity to process all environmental signals. Steele & Josephs (1990) term this phenomenon „alcohol myopia‟: a state of short-sightedness in which we process fewer cues less well.

CAFFEINE

Caffeine is regarded as one the most widely consumed psychoactive stimulants in the world (Nehlig, Daval, & Debry, 1992; James, 1998; Lieberman, 2001; Smith, 2002; Snel, Lorist, and Tieges, 2004; Brunyé, Mahoney, Lieberman, Giles, & Taylor, 2010). Therefore, studies into its pharmacological effects are considered to be of great importance, and so these effects have been the focus of much attention. These studies have concluded that many of caffeine‟s effects are mediated through antagonism of the adenosine receptor: however, some effects

derive from inhibition of phosphodiesterase (Moskowitz, Burns, 1981; Robertson, Wade, Workman, Woosley, & Oates, 1981; Hasenfratz, Bunge, Dal Prá, & Bättig, 1993; Liguori & Robinson, 2001; Maisto, Galizio, & Connors, 1991; van Duinen *et al*., 2005)

It is well established that caffeine has the ability to act as a stimulant on both the peripheral and central nervous systems (Maisto *et al*., 1991). Caffeine‟s mechanism of action is the occupation of the adenosine receptors and blocking the action of various neurotransmitters within the body (Maisto, *et al*., 1991; Smith, 2002). Caffeine therefore increases the levels of several neurotransmitters such as dopamine, acetylcholine and serotonin. Furthermore, Brunyé *et al*. (2010) hold caffeine to be a highly reliable catalyst for dopaminergic availability through its antagonistic effects on adenosine, causing higher levels of arousal and increased attention (alertness/vigilance).

Caffeine is rapidly and almost completely (99%) absorbed from the gastrointestinal tract and quickly reaches the brain (Lorist & Tops, 2003). Owing to its ability to permeate all biological membranes, including those of the blood-brain barrier and the placental barrier, caffeine has the ability to affect the body speedily: peak plasma concentration occurs approximately 15 – 45 minutes after ingestion (Smith, 2002; Snel, Lorist, and Tieges, 2004). Other researchers contend that peak plasma caffeine concentration is reached between 15 and 120 minutes after oral dosage (Valladares, Cosic, and Bedford, 2009).Further support comes from Lorist & Tops (2003), who state that peak plasma concentrations are reached in about 30–60 minutes after consumption. Once caffeine is ingested, it is equally distributed in total body water. Therefore, the concentration of caffeine is similar throughout the body (Maisto *et al*.,1991).

Caffeine elimination takes place primarily by metabolism in the liver (Lorist & Tops, 2003). It is stated that caffeine affects individuals differently, with a half-life ranging between 2.5 and 7.5 hours (Maisto *et al*., 1991). Other researchers argue that the half-life of caffeine is approximately 3–5 hours, although individual clearance rates vary considerably (Smith, 2002). Elimination rates are said to be affected by a number of variables, including nicotine (30–50% increase in elimination) and when women consume oral contraceptives (elimination rate doubles), as stated by Lorist & Tops (2003).

Acute effects of caffeine

The primary action of caffeine is stimulation of central nervous system activity. However, as stated before, caffeine also affects the periphery of the body (outside the central nervous system). The acute physiological effects of caffeine include, but are not limited to: increased heart rate, contraction of striated muscle, relaxation of smooth muscle, diuretic effects on the kidneys, a stimulating effect on respiration, elevation of basal metabolism as well as various enzymatic and endocrine effects (Maisto *et al.*, 1991; Boyle & Long, 2010). Furthermore, caffeine has the ability to enhance human vigilance and mental alertness (Brunyé *et al*., 2010), and increase arousal, attention, and information processing. These in turn translate into improvements in accuracy and speeded responses on simple and choice reaction time tasks. Caffeine also has certain behavioural effects on the human body including the elevation of mood as well as profound performance effects (Table III).

Table III: Performance effect of Caffeine (adapted from Maisto *et al*., (1991).

Performance Variable	Effect of Caffeine
Physical endurance	Increases
Motor skills	
Hand-eye coordination	Decreases
Rapidity and accuracy	Decreases at high doses, Increases at lower doses
Vigilance Tasks	Increases
Reaction time	
Simple RT	Decreases (speeds up)
Choice RT	
Decision time	Decreases
Motor time	No effect
Accuracy	Increases (a.m), Decreases (p.m)
Time stress accuracy	
Introverts	Increases
Extroverts	Decreases

The effects of caffeine are dose dependent, affecting performance to a greater degree with higher doses of caffeine. The effects are most pronounced when subjects perform under

suboptimal conditions, characterized by fatigue or monotony, or in tasks placing high demands on the information processing system (Van Duinen *et al*., 2005).

Impact of caffeine on information processing

Although there is no strong agreement on the effects of caffeine on specific cognitive operations, there are indications that caffeine affects the attention system (Maisto *et al*., 1991). In this next section results indicate that the information processing system appears more sensitive to the stimulus characteristics after caffeine consumption.

Caffeine and visual perceptual performance

Attempting to test the effects of caffeine on perception and visual processing, many studies have employed the use of visual detection tasks (Kenemans & Lorist, 1995; Lorist & Snel, 1997; Newton, 2009; Brunyé *et al.,* 2010). Others argue that low to moderate doses of caffeine have no direct effect on sensory functions (Lieberman, 2001) taking into account that no well- controlled studies utilising state-of-the-art methodologies and equipment have yet been used (Smith, 2002).

Baker & Theologus (1972) were among the first authors to study caffeine"s effects on visual monitoring. These two authors discovered that caffeine administration significantly reduced response latency in a visual monitoring task. The authors implemented two doses of caffeine (200 mg and 400 mg) and compared response latencies of these doses to a control (placebo) group. In both caffeine conditions, response latency was significantly reduced in comparison to that of the control group. The response latency in the 200 mg condition was slightly less than that in the 400 mg condition (Baker & Theologus, 1972). Further, within conditions involving caffeine consumption, response blocking was substantially reduced, with more response blocks being observed in the control group. These authors contend that caffeine helps to repress the tendency toward response blocking that is generated by extended performance on a monotonous task. Furthermore, the authors argue that the simulated task and the response obtained can be extrapolated to tasks such as long term monotonous night driving.

Caffeine and cognitive performance

Caffeine‟s effect on cognition has been implicated in both simple and higher order cognitive tasks (Brunyé *et al*., 2010). Many studies have reported that caffeine ingestion enhances human performance - these effects are however somewhat equivocal. Findings variously indicate improvements, no effect, or decrements in cognitive performance following caffeine ingestion (Lorist & Snel, 1997; James, 1998; Kenemans, Wieleman, Zeegers, & Verbaten, 1999).

Reaction time tests have been the basis of many caffeine-related cognitive performance studies and have been used as indicators of overall cognitive performance. Van Duinen *et al*., (2005) stated that cognitive performance - by measurement of choice reaction time - was more efficient in conditions involving caffeine consumption. These authors further contend that the positive effects of caffeine were most robust on tasks associated with attention or alertness. Furthermore, in conditions involving dual-task performance and caffeine consumption, cognitive performance was maintained. Conversely, in placebo conditions involving a dual-task paradigm, a deterioration of cognitive performance was evident (Van Duinen *et al*., 2005). The authors attributed this deterioration in performance to the limited capacity of the information processing system. Thus, when demands placed on the system were higher than the capacity of the information processing system, deterioration in performance was the result. However, in conditions involving caffeine consumption there was no increase in reaction times in the beginning of the dual task, indicating that caffeine did have an influence on the information processing capacity. This finding is consistent with several other studies, which showed that in cognitive dual-task performance, caffeine has a positive effect on performance (Ruijter, Lorist, & Snel, 1999; Brice, & Smith, 2002).

Enhancements in higher- order cognitive functioning include a reduction in response time during task switching, heightened response inhibition, as well as a reduction in task interference during the Stroop test, wordlist recall, and other selective visual attention tasks (Brunyé *et al*., 2010). Complex cognitive task effects are equivocal, because of the moderating influence of factors such as personality and time of day. However, even this area shows few costs of caffeine consumption.

Brunyé *et al*. (2010) measured the relative function of the alerting, orienting and executive control networks through the use of a modified flanker task. In general, these authors established that caffeine improved the efficiency with which participants could take advantage of cues that alerted them to trial onset, and further improved the ability to efficiently inhibit the influence of action-incompatible stimuli. This finding illustrates the positive effects of caffeine on tasks requiring speeded responses and continuous vigilance. This finding is consistent with several other studies (Fine, Kobrick, Lieberman, Marlowe, Riley and Tharion, 1994; Kenemans & Lorist, 1995; Lieberman, 2001; Wesensten, Killgore, & Balkin, 2005)

In terms of memory, Erikson, Hager, Houseworth, Duggan, Petros and Beckwith, (1985) conducted a study into the effects of caffeine on memory. This author measured recall and rehearsal on word lists and established that caffeine may impair the efficiency with which females rehearse information in working memory. Conversely, Arnold, Petros, Beckwith, Coons, and Gorman, (1987) established that caffeine facilitated recall in females after practice with the task, but impaired recall in males at a medium dose. It can be suggested that the effects of caffeine on females varies according to the level of oestrogen and other hormones within the subjects‟ systems. In a study conducted by Loke (1988), subjects were required to complete a battery of tests in both pre-drug and post -drug conditions. Results indicated that caffeine showed non-significant effects on cognition, learning and memory performance.

Caffeine and motor performance

Experimental findings on the effects of caffeine on the motor system are rather inconsistent (Lorist & Snel, 1997). Of the many indices of human performance that have been included in studies of caffeine, the most consistent results have been obtained in relation to simple motor responses (James, 1998). Improvements in motor and psychomotor tasks such as digit-symbol substitution, stimulus recognition, and vigilance tracking have been at the forefront of many findings (James, 1998). However, this author argues that caffeine consumption may undermine performance on activities that require precise motor control (as suggested by measurements of decreased hand steadiness).

Jacobson and Edgley (1987) found that simple reaction time and movement time were significantly shortened after 300 mg caffeine, however reaction times for a dose of 600 mg were not significantly different to the 300 mg dose. Lorist & Snel (1997), established that simple reaction time as measured by the flanker test was shorter in conditions involving caffeine consumption with the opposite finding occurring in placebo conditions. Further, these authors state that when flankers were present reaction times were slower than in comparison to stimuli without flankers.

The caffeine-related effects on muscle force are contradictory. Certain studies have failed to show significant ergogenic effects (Lopes, Aubier, Jardim, Aranda, and Macklem, 1983; Williams, Barnes, & Gadberry, 1987), whereas others have found increases after caffeine administration. Van Duinen *et al*. (2005) established that caffeine had no effect on motor parameters of absolute force, time course of the MVCs or endurance time. This was also the case in two studies utilizing higher caffeine doses. Kalmar & Cafarelli, (2004) and Williams, Barnes & Gadberry (1987) found no increase in motor parameters when implementing doses of 6 mg/kg and 7 mg/kg respectively.

The activation of the motor system can be influenced by preliminary phases of stimulus evaluation.

Dose administration and selection

In previous studies, the doses used varied from a single dose of 32 mg (Lieberman, Wurtman, Emde, Roberts and Coviella, 1987) up to 1,400 mg of caffeine, or body weight-related doses of 1 to 13 mg/kg (Van Duinen *et al*., 2005). Graham (2001) contends that the optimal dose of caffeine - to mimic everyday life consumption - is between 3 and 6 mg per kilogram of body weight. This finding is supported by Brunyé *et al*. (2010) who states that 3 mg/kg is the typical dose administered in most caffeine trials. However, these authors have found this dose to be ineffective for individuals who have relatively high caffeine consumption profiles. Brunyé *et al*. (2010) assert that higher doses of caffeine (~170-340 mg) should therefore be used to elicit changes in higher order cognitive functions. These authors hypothesized that 200 mg will not be sufficient to modulate lower- or higher- order cognitive processes related to the deployment and control of visual attention. Results obtained by Brunyé *et al*. (2010) confirmed

this hypothesis and further proved that a 400 mg dose (5 mg/kg for an 80 kg individual) produced significant effects in lower and higher-order cognitive functions.

What should be noted is that doses of caffeine as high as those implemented by the abovementioned researchers are not typical in everyday drinks and foods, and as such do not replicate everyday scenarios (Smith, 2002). According to Maisto *et al*. (1991), the average caffeine consumption by an individual South African is approximately 40 mg/day. Therefore, implementing high doses of caffeine to participants will not depict everyday South African consumption. One researcher posits that an inverted U-shaped dose–response curve for caffeine occurs, with lower doses having positive effects on performance, while doses above 500 mg cause a decrease in performance (Lorist & Tops, 2003).

Caffeine-alcohol antagonism

More recent literature contends that caffeine has the ability to antagonise the effect of alcohol impairment (Moskowitz & Burns, 1981; Hasenfratz *et al*., 1993; Liguori & Robinson, 2001; Marczinski & Fillmore, 2003). The capability of caffeine to antagonise the impairing effects of alcohol has been attributed to caffeine's ability to reduce the rate of alcohol absorption. Furthermore it has been found that, because caffeine acts as a central nervous system stimulant - increasing heart rate and arousal levels and promoting efficient information processing –it improved alcohol-impaired rapid information processing performance at low to moderate blood alcohol levels (Hasenfratz *et al*., 1993). This antagonistic effect suggests that caffeine has the ability to offset the debilitating effects of alcohol. Moskowitz & Burns (1981) reported antagonism of driving impairments for breath alcohol concentrations between 0.05 and 0.06 %, but not at 0.11%. Liguori & Robinson (2001) observed limited antagonism at a breath alcohol concentration of 0.08%. This therefore suggests that caffeine antagonism to alcohol impairment is present under conditions of low–moderate blood alcohol concentrations (0.07%).

In a cued go/no- go reaction time task, Marczinski & Fillmore (2003) observed that caffeine antagonised alcohol-induced impairment of response execution, but had no antagonising effect on response inhibition.

Although caffeine demonstrates an antagonising/additive effect on performance under conditions of caffeine and alcohol consumption, the evidence for caffeine reducing breath alcohol concentration is lacking. A number of researchers have demonstrated that the combination of caffeine and alcohol consumption produce a relatively similar blood alcohol concentration compared to that of alcohol-only consumption (Hasenfratz *et al*., 1993; Liguori & Robinson, 2001; Marczinski & Fillmore, 2003).

Liguori & Robinson (2001) reported that the combination of caffeine and alcohol reduced heart rate responses post- ingestion across all time parameters (45, 75, 105 minutes). During the 75th minute heart rate was significantly lower than that of the alcohol and control groups. Further, the decrease in heart rate was dose dependent, with the higher dose of caffeine (400 mg) reducing heart rate to a greater extent than that of the lower dose (200 mg).

METHODOLOGICAL DISCREPANCIES

Many of the discrepancies in the alcohol-related and caffeine-related literature can be attributed to variations in experimental design and methodological design principles (Brunyé *et al*., 2010; Fransson *et al*., 2010; Roche & King, 2010). Coupled with this is the inconsistent use of alcohol and caffeine in the various studies. Some of these methodological differences lie in the duration of alcohol/caffeine abstinence, dose of alcohol/caffeine and manner of administration. Other discrepancies may include environmental circumstances and individual tolerance differences (Miller, Lombardo, & Fowler, 1995).

Further, in certain caffeine studies, subjects were required to abstain from coffee for just 1 hour before the experiment, while other studies demand abstinence from caffeine for several days (Van Duinen *et al*., 2005). Certain studies have encouraged participants to consume their normal morning cup of coffee, to avoid any withdrawal effects.

CIRCADIAN RHYTHM

The circadian rhythm, also known as a human"s internal biological clock, is an approximate 24 hour cycle structured within physiological processes (Kelly, 1996). Circadian rhythms are endogenously generated and are entrained to external cues such as sunlight and temperature (Kelly, 1996). This rhythm is controlled within the suprachiasmatic nucleus of the

hypothalamus and acts as an endogenous regulatory system responsible for the control of behaviour throughout the duration of an individual‟s wakeful period (Figure 3). Circadian rhythm regulates the bodily functions by affecting the levels of fatigue, arousal/alertness, performance, sleep and wakefulness of each individual (Van Dongen & Dinges, 2005; Esteki & Sadeghi, 2010).

Circadian variation is incorporative of the amount of wakefulness (arousal/ alertness) as well as the concurrent sleep load throughout the day (Figure 3). The increasing circadian rhythm produces an increase in alertness, reaching two peaks each day, mid-morning and evening. Similarly, the decreasing circadian rhythm results in two troughs (Nadirs‟) that correspond with a post-lunch time and early morning nadir.

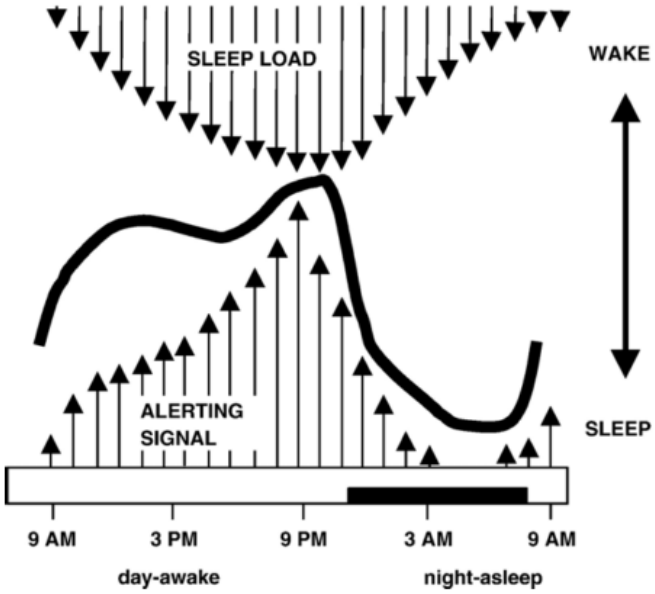

Figure 3: Circadian rhythm, indicating alertness and sleep load (Blatter & Cajochen, 2007)

As an individual‟s period of wakefulness increases, so the corresponding sleep load (the need for sleep) increases. Blatter & Cajochen (2007) point out that sleep load diminishes once an individual has rested. Observed from the combination of increased sleep load and the oscillatory circadian rhythm, it is evident that an individual is most alert during the day and is less alert during the evening and early hours of the morning.

Early investigations in circadian variation demonstrated that performance was dependent on the diurnal variation in body temperature (Kleitman, 1933; Blatter & Cajochen, 2007). Kleitman (1933) noticed that the relationship between reaction and body temperature was inverse, with an increased body temperature inferring a reduced reaction time. In addition to reaction times, Kleitman (1933) also investigated more complex performance measures such as card sorting, mirror drawing, code transcription and multiplication speed: these all demonstrated a consistent temporal relationship with the diurnal rhythm of body temperature and heart rate(Figure 4). Therefore, cognitive performance is seen to be affected by both body temperature and circadian rhythm (Blatter & Cajochen, 2007).

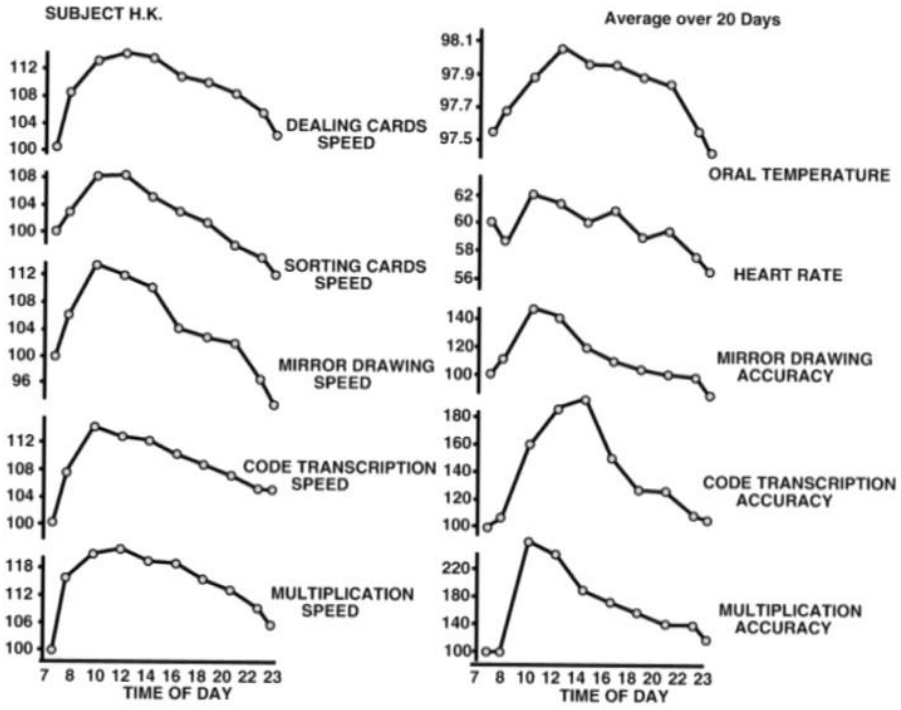

Figure 4: Diurnal variation in performance (speed vs. accuracy) (Blatter & Cajochen, 2007)

As seen in Figure 4, speed and accuracy in task performance follow the similar circadian variation as observed in Figure 3. Blatter & Cajochen (2007), point out that body temperature is not the only confounding variable on circadian performance. Moreover, task complexity (load, duration & pacing) and individual variation are two crucial roles in rhythm performance.

Circadian impact on alcohol consumption

Research indicates that a temporal or circadian factor (time of day) effects the severity of alcohol impairment. Studies indicate that the time of day in which the experimental session takes place will affect the level of intoxication (Jones, 1974; Maisto, Connors and Vuchinich, 1978). These researchers contend that when alcohol is consumed in the evening, a lesser deficit was observed in cognitive performance, compared to when alcohol is ingested in the afternoon. Wasielewski and Holloway (2001) argue that this effect may be explained by metabolism and elimination of the drug as well as the degree to which the drug binds to molecules in the bloodstream or to other tissues in the body. In addition, the metabolism and elimination rates of a drug are often influenced by the time of day at which it enters the system, thereby affecting the relative breakdown of the drug.

Acute effects of alcohol on body temperature

Few studies have focussed on the effect of alcohol on core body temperature. Danel, Libersa & Touitou (2001) and Wasielewski & Holloway (2001) reported that the effect of alcohol on body temperature is time dependent, demonstrating a hypothermic effect when a single dose of ethanol is administered. With further investigation into the effect of repeated alcohol intake over a 24 hour period, Danel *et al*. (2001), observed a general hypothermic effect during the day. Conversely, body temperature during night experimentation revealed a significant hyperthermic effect, which reduced the total circadian amplitude of core body temperature by 43%. The investigation suggests that situations that alter body temperature, including shift work, may be aggravated by alcohol intake (Danel *et al*., 2001).

Devaney, Graham & Greeley (2003) demonstrated that alcohol ingestion resulted in a hypothermic effect during morning experimentation (10:00) with no effect demonstrated during evening experimentation (18:00). Conversely, a hyperthermic effect was found between 23:30 and 8:30, irrespective of the time of ingestion (Devaney, Graham & Greeley, 2003).

It is speculated that alcohol produces dysregulation of the thermoregulatory system (Wasielewski & Holloway, 2001). This thermodysregulation raises body temperature to higher than normal when the ambient temperature is warm and decreases body temperature when

ambient temperature is cool (Wasielewski & Holloway, 2001). Further, these researchers contend that this dysregulation occurs in a part of the brain responsible for the processing of incoming sensory stimuli.

It is suggested that these changes in body temperature are the result of increased activation of all nerve-cell-communication chemicals; with a particularly higher increase in norepinephrine and serotonin secretion (Huttunen, 1990; Alkana, Davies, & Le, 1996). Alternatively, Cranshaw, O"Connor, & Wollmuth (1992) demonstrated drops in body temperature to be associated with higher levels of serotonin.

Body temperature has been shown to be a pertinent factor in the rate of metabolism and elimination of alcohol from the body (Wasielewski & Holloway, 2001). These researchers report that a hypothermic state decreases the rate of chemical reactions thereby slowing the rate of elimination by approximately 50 – 60 percent.

Circadian impact on caffeine consumption

Research suggests that the effects of caffeine consumption vary with the time of day (Miller *et al*., 1995). These authors postulate that circadian variations in the pharmacological action for many different substances - from barbiturates to amphetamines as well as alcohol - have been found. Miller *et al*. (1995) observed a significant effect of caffeine on force production in the morning, while no such effect was observed in afternoon or evening sessions (Miller *et al*., 1995). In a Study conducted by (Mitchell and Redman, 1992), it was established that caffeine improved visual serial search task performance: however, this was only observed in experimental sessions occurring in the morning.

In elderly individuals, Ryan *et al*. (2002) observed that participants who ingested decaffeinated coffee showed a significant reduction in memory performance from morning to afternoon. Conversely, those who ingested caffeine showed no decline in performance from morning to afternoon. Further, Ryan *et al*. (2002) demonstrated that short-delay recall was not sensitive to time of day, but did show a difference for caffeine dose; with participants who consumed caffeine recalling significantly more items than those participants that did not. In this same study, caffeine modified the time of day effect for recognition hit rate, illustrating a

significant effect for time of day and caffeine type. This effect indicated that participants who did not consume caffeine incurred a significant drop in hit rate compared to caffeine individuals, who maintained a relatively constant hit rate. These authors suggest that time of day effects may be mediated by nonspecific changes in level of arousal.

Acute effects of caffeine on body temperature

While few studies have been conducted into caffeine and circadian rhythm, even fewer have measured body temperature concurrently. Wright, Badia, Myers, Plenzler, & Hakel (1997), reported that both caffeine and light have been shown to attenuate night time drop in temperature. Caffeine consumption (200 mg) elicited consistent increases in body temperature throughout experimentation. Although this result was non-significant, temperature was consistently elevated when compared to the participants‟ control trial. Furthermore, when caffeine consumption was combined with bright light exposure, body temperature was significantly high when compared to the participants‟ placebo exposure (Wright *et al*., 1997). These researchers contend that caffeine consumption in combination with bright light exposure prevented the normal night time decrease in temperature.

HEART RATE VARIABILITY

Heart rate variability has been studied extensively and has been termed an important marker of autonomic nervous system modulation (Luft, Takase, & Darby, 2009; Task Force, 1996). Heart rate variability is the physiological parameter which measures the beat-to-beat variations in heart rate (Huysamen, 2011). Efficient functioning and homeostasis of the body in a complex environment requires a dynamic interplay between the sympathetic nervous system and the parasympathetic nervous system (Luft *et al*., 2009). The variation in heart rate variability results from these continuous changes in the sympathetic and parasympathetic balance, stimulating the sinus rhythm to exhibit fluctuations around the mean heart rate (Huysamen, 2011).

Measurement of heart rate variability

Analysis methods of heart rate variability include both the time-domain and frequency-domain analyses (Jorna, 1992).

Time-domain analyses

There are a number of different time-domain analyses that can be performed. This study measured four different analyses, namely SDNN, RMSSD, PNN50, and the PNN30 (an altered version of the PNN50). SDNN refers to the mean difference between all adjacent beat-to-beat (N-N) intervals, while RMSSD calculates the square root of the mean of the sum of squares differences between adjacent N-N intervals. The PNN50 evaluates the percentage of adjacent N-N intervals that differed by more than 50 ms compared to the total N-N interval. PNN30 is calculated identically to the PNN50, using 30 ms as the differentiation criterion – this variable was constructed in order to improve identification of phases with lower variability.

Frequency-domain analyses

Frequency-domain analyses decompose the HRV signal into separate frequency ranges. The most widely used - in the case of mental workload - being high frequency (0.15-0.4 Hz) and low frequency (0.04-0.15 Hz) (Jorna, 1992). The low frequency spectrum reflects sympathetic modulation/activity while the high frequency band reflects vagal/ parasympathetic activation and respiration (Berntson *et al*.,1997). This study analysed both high frequency and low frequency spectra, which were calculated using the Fourier transformation (FFT). For each frequency band both the total power and the centre frequency were calculated – the power variable reflects the total power within the band in ms^2, while the centre frequency considers the frequency at which the power spectrum is split into two portions of equal power (Hz).

The ratio between low and high frequency has also been suggested by various authors to reflect sympathetic modulations (Miyake, 2001 and Lin *et al*., 2008;). For this analysis, the percentage of the low frequency component relative to the total (LF+HF) power was also calculated.

Heart rate variability and cognitive workload

Heart rate variability has been widely accepted as an indicator of mental effort and cognitive processing closely related to arousal and attention (Rowe, Sibert, & Irwin, 1998). Further, this physiological parameter has been shown to be sensitive to changes in mental effort (Huysamen, 2011; Rowe *et al*., 1998). Luft *et al*. (2009) concluded that heart rate variability is

related to cognitive demand, in that decrements in heart rate variability (indicating increased cognitive effort) were demonstrated for simple reaction time, choice reaction time, working memory, short-term memory and sustained attention. Researchers propose that an increase in heart rate variability is driven by the parasympathetic nervous system and indicates low cognitive resource utilization (Berntson *et al.,* 1997; Segerstrom & Solberg Nes, 2007). Conversely, decreased heart rate variability is driven by the sympathetic nervous system and thus indicates a more difficult cognitive task or increased workload. This finding has been supported by the works of Luft *et al*., (2009), who establish a correlation between heart rate variability and cognitive performance.

Acute effects of alcohol on heart rate and heart rate variability

There are a limited number of studies, to our knowledge, that have focused specifically on heart rate variability and cognitive performance while under the influence of alcohol. Alcohol ingestion is widely considered to have an increasing effect on heart rate (Sayette, 1993; Conrod, Peterson, Pihl and Mankowski, 1997; Conrod, Peterson, & Pihl, 2001). At low doses of ingestion, the increased heart rate has been attributed to a reduction in parasympathetic (vagal) activity; while at higher doses, alcohol has elicited a decrease in heart rate (Sayette, 1993). This author further contends that the increase in basal heart rate associated with alcohol consumption requires approximately 35-40 minutes absorption time. Conrod *et al.* (1997) demonstrate a large increase in heart rate during the ascending limb of the blood alcohol concentration curve post alcohol consumption. Similarly, although to a lesser degree, an increase in heart rate was observed on the descending limb of the blood alcohol curve. In a later study, Conrod *et al*. (2001) proposed that alcohol-induced heart rate increase reflects a specific sensitivity to the psychomotor stimulant properties of alcohol.

Limited studies have been conducted on heart rate variability and performance while under the influence of alcohol. Koskinen, Virolainen, & Kupari (1994) measured heart rate variability in both time domain and frequency domain analyses in healthy subjects. These authors observed that the acute intake of alcohol resulted in a significant decrease in short term heart rate variability. Koskinen *et al.,* (1994) demonstrated a significant suppression of beat-beat interval variability and of the root mean square beat-beat interval variability (RMSSD).

Furthermore, a significantly lowered high-frequency component was observed during ethanol ingestion. Rossinen *et al*. (1997) observed that alcohol consumption decreases RMSSD, High Frequency Power and total variability. The Low Frequency Power and the Very Low Frequency Power components are significantly reduced when alcohol has been consumed. It should be noted, that Rossinen *et al*. (1997) measured heart rate variability over a 24 hour period in patients with symptoms of coronary heart disease. However, with the limited number of studies regarding alcohol consumption and heart rate variability, this studies provides pertinent information regarding the effects of alcohol consumption on heart rate variability

EYE MOVEMENT ANALYSIS

A thorough review of eye movement analysis is beyond the scope of this investigation, therefore the necessary measures applied to this study will be the focus of this review. Eye motion analysis has been widely used to study visual fatigue and performance (Anderson, 2010). These studies have made use of saccades (velocity and amplitude), pupil diameter, blink frequency, blink duration and fixation duration to infer states of fatigue and performance.

Saccades

Saccadic eye movements are rapid conjugate shifts of gaze of both eyes in the same direction (Griffiths, Marshall, & Richens, 1984) Movement of the eyes to fixate on a target or indeed any other movement, requires control of the amplitude of movement and the direction of the movement (Anderson, 2010). The amplitude determines the saccade accuracy while duration is the time taken to complete the saccade. The amplitude determines the saccade accuracy while duration is the time taken to complete the saccade. The amplitude of the saccade refers to the distance between the various saccades, while saccade velocity indicates the speed at which the amplitude is covered. Griffiths *et al*. (1984, p 74) state, “peak saccade velocity and saccade duration are indicators of brain stem reticular formation function, while saccade reaction time is a marker of higher central nervous system function”. Further, it is stated that peak saccade velocity and saccade duration are sensitive measures of central nervous system depression. Therefore, a decrease in saccade speed is representative of increased central nervous system depression. In a review of eye motion data, Chaplin (2010) states that fatigue is demonstrated by a reduced peak saccade velocity.

Fixation duration

Fixation duration is a measurement representing the time the eyes remain fixed on a stimulus prior to the initiation of a saccade (Rayner, 1998). An increased duration of fixations has been correlated to an increase in fatigue (Chaplin, 2010) and an increase in sleepiness (Schleicher, Galley, Briest, & Galley, 2008).

Blink frequency and duration

Eye Blink Frequency is defined as the number of blinks that occur in one minute; the duration of these blinks is termed the Blink Duration (Roche & King, 2010). Eye Blink Duration and Frequency are considered oculomotoric indicators of alertness and thus fatigue (Schleicher *et al*., 2008). Increased Eye Blink Duration and Frequency are indicative of the onset of fatigue.

Pupil size

Pupil size refers to the diameter of the pupil as it changes between tasks and task demands. Pupil diameter may change for a variety of reasons, including memory load, cognitive difficulty, valence, arousal and pain (Wang, 2009). Pupil diameter changes in response to mental workload, increasing when performing cognitively demanding processes.

Acute effects of alcohol on eye movements

Few studies have investigated oculomotor performance under the influence of alcohol. Fransson *et al*. (2010) report that the deterioration in nerve impulse transmission due to the effects of alcohol may lead to increased latency of all motor function responses such as saccadic and smooth pursuit eye movements and poorer eye movement control. Consensus has been reached that alcohol affects oculomotor parameters in a dose dependent manner, with effects on saccades and smooth pursuit movements above 0.05% blood alcohol concentration (Ando, Johanson, & Schuster, 1987; Fransson *et al*., 2010; Roche & King, 2010). While several studies have focused on smooth pursuit eye movements, fewer studies have focused on saccadic eye parameters (Roche & King, 2010).

Ethanol is believed to disrupt smooth pursuit eye movements by causing eye velocity to lag behind target velocity and frequent saccades are thus required to maintain focus, resulting in

a pattern known as saccadic pursuit (Levy, Lipton, & Holzman, 1981). Griffiths *et al*., (1984), report that saccadic eye movement‟s decrease in velocity and increase in duration under the influence of alcohol.

Ando, Johanson & Schuster (1987) reported that pursuit eye movements were disrupted at doses of 0.05 g/kg in both monkeys and humans. Alcohol has been shown to significantly impair smooth pursuit gain as well as pro- and anti-saccade latency, velocity, and accuracy in a dose- and time- specific manner (Roche & King, 2010). These researchers reported that a high dose of alcohol (0.8 g/kg) induced impairment in all eye movement measurements, while a moderate dose of alcohol (0.4 g/kg) produced a lesser impairment that was only apparent at peak BrAC.

Fransson *et al*. (2010) demonstrated that alcohol significantly deteriorated accuracy of smooth pursuit movements and saccadic velocities at 0.06% blood alcohol concentration, while at a blood alcohol concentration of 0.10%, smooth pursuit gains, saccade accuracies and saccade latencies were also significantly affected. Furthermore, these researchers observed a significant decrease in the ratio between saccade velocity and saccade amplitude under alcohol intoxication.

Wegner & Fahle (1999) demonstrated a 20% increase in saccadic latency and speed in participants with a blood alcohol concentration varying between 0.06% and 0.13%. Fransson *et al*. (2010) suggest that peak saccade velocities may be impaired at blood alcohol concentrations as low as 0.06%.

CHAPTER III

METHODOLOGY

INTRODUCTION

The aim of this research was firstly to establish task-related alcohol impairment on human information processing resources at a visual, cognitive and motor level. Secondly, to establish how the consumption of caffeine prior to alcohol consumption affected this impairment. Furthermore, this investigation implemented two task complexities to assess the effects of alcohol consumption and caffeine antagonism at varying task complexities. This aspect of the investigation sought to determine the degree of resource utilisation in each stage of the information processing stream. Analysis followed that of an experimental approach, involving the simulation of an alcohol impairment study within a laboratory setting. The study utilized low to moderate doses of alcohol in order to establish the effects of alcohol on human information processing at the government-imposed legal limit (0.05% blood alcohol concentration) as well as at doses slightly above this benchmark. Furthermore, a caffeine stimulant was implemented to test the antagonistic effects of prior caffeine consumption on alcohol impairment at low to moderate breath alcohol concentrations. These two variables were investigated in daytime versus night experimental sessions, to quantify time of day effects of alcohol and caffeine antagonism on human information processing performance. A covariate of gender was implemented in order to establish sex-related differences in response to the afore-mentioned variables.

EXPERIMENTAL DESIGN

The aims of this investigation were investigated by comparing baseline test measures of six resource- specific tasks to performance in the same tasks on the inclining and declining phases of the blood alcohol curve. Further, to establish the antagonistic effects of caffeine on alcohol impairment, experimentation remained the same except that caffeine was administered prior to alcohol consumption. Quantification of resource utilisation was achieved by implementing simple and complex trials of each task. The difference in performance measured between these two complexities would illustrate the extent to which the task-

specific resources were depleted. Three groups of participants (two experimental and one control) were used in this investigation to test the hypotheses. The experimental groups were designed so that one group (hereafter referred to as the *alcohol* group) would receive a single dose of alcohol to affect a maximum level of 0.075 % blood alcohol concentration. The group consuming both caffeine and alcohol (hereafter referred to as the *caffeine+alcohol* group) received the stimulant first (4 mg/kg body weight) and the depressant (same dose as above) 20 minutes post caffeine consumption. The *control* group received neither alcohol nor caffeine, and was used to provide a reference group for all measures. Each group comprised 36 participants split evenly between male and female sexes.

Independent variables

Alcohol consumption

Alcohol was administered in a single dose to affect a maximum dose of 0.075% blood alcohol concentration (0.375 mg/L). The type of alcohol administered in this analysis was a spirit, vodka. This specific vodka spirit (Russian Bear) had an alcohol volume of 40%. The dose of alcohol administered to each participant was based on the Widmark equation (Equation 1). Participants were administered vodka diluted with sugar-free flavoured water upon the completion of the baseline test measures. The time of alcohol administration was noted and recorded. The required dosage of alcohol was measured with the aid of a 60 ml syringe and divided into two beverages. In order to standardise dosage, the principal researcher measured and administered each dose to participants. In an attempt to control rate of absorption drinking tome was standardised and participants were asked to consume both beverages within two minutes.

Equation 1: The Widmark Equation of breath alcohol concentration

$$A = (C \times G \times r) \div 100$$

Where:
- (A) is the quantity of alcohol (g)
- (C) is the alcohol concentration in the blood (in mg/100 ml)
- (G) is the body weight
- (r) is a diffusion factor (0.7 for males and 0.6 for females)

Caffeine stimulant

The *caffeine+alcohol* group was administered a caffeine stimulant to quantify whether or not caffeine had an antagonistic effect on alcohol impairment. Caffeine was therefore the second independent variable under study. In conditions involving caffeine ingestion, participants were administered a 4 mg/kg BW dose, in capsule form. This criterion was based on the works of several caffeine studies, which agree that a dose between 3 and 6 mg/kg is the optimal dose of caffeine to ingest to mimic everyday caffeine consumption (Graham, 2001; Smith, 2002; Lorist & Tops, 2003; van Duinen *et al.,* 2005; Brunyé *et al*., 2010). Further, these authors contend that this dose is neither too low to be ineffective nor too high to elicit negative performance effects.

The dose was administered immediately after the completion of the baseline test condition and 40 minutes prior to alcohol consumption. This allowed sufficient time for the stimulant to take effect before alcohol was consumed. This criterion was based on the works of Maisto *et al*., (1991) who contend that caffeine takes approximately 15 – 45 minutes to affect the central and peripheral nervous systems and this criterion is further supported by (Marks & Kelly, 1973; Valladares, Cosic, and Bedford, 2009). Upon the completion of test battery 1 (pure caffeine), participants from the *caffeine+alcohol* group were required to consume the alcohol dose. Caffeine dosing was structured to ensure that baseline comparisons and pure caffeine effects could be established which could then be compared to conditions involving the influence of alcohol.

Time of day effects

Studies indicate that the time of day in which the experimental session takes place will affect the level of intoxication (Jones, 1974; Maisto *et al*., 1991; Wasielewski & Holloway, 2001). These researchers contend that when alcohol is consumed in the evening, a lesser deficit will be observed in cognitive performance, compared to afternoon alcohol ingestion. A time of day effect has therefore been implemented as the third independent variable. The purpose of this was to quantify the effects of alcohol intoxication at two different times of day.

In order to standardise testing times, participants from the experimental groups were required to utilize one of two time slots, 10:00 - 12:30 and 10:30 – 13:00 in the morning and 19:00 -

21:30 or 19:30 – 22:00 at night. The control participants were tested at the same times each day between the following times, 08:00 – 10:00 and 17:00 – 19:00. These experimental times were chosen as they coincide with two rising peaks of the circadian rhythm (Figure 4); and as a result performance should not be affected by the circadian nadirs present in the day to day rhythm. This staggered testing design allowed two participants to be tested simultaneously. The order of participants‟ sessions was permutated evenly across both groups with an equal number of subjects from each group starting in the earlier slot (Appendix C). This ensured that any changes in performance between groups could be attributed to the time of day, alcohol and/or caffeine.

Body posture, lighting conditions and food intake were kept constant throughout testing in an attempt to reduce these external masking factors on circadian rhythm and hence the measured variables. Internal masking factors (e.g. stress levels, digestion and motivation) were more difficult to control; however, each participant was treated in exactly the same manner to control these factors where possible. Meticulous efforts were made to reduce these external and internal extraneous cues, in an attempt to reduce their masking influences on the measured variables.

Resources-specific tasks

The six resource-specific tasks implemented in this investigation to test the aims and hypotheses are the final independent variables within this study. These tasks were designed using proven scientific principals and laws to test the visual perceptual, cognitive and motor performance. The six tasks were tested in simple and complex trials in each test battery, with the average between these two trials indicating average task-related performance, whereas the difference between complex and simple trials indicated resource utilization and depletion (differential performance). The task implemented to measure visual perception were an accommodation task, a visual detection task and a reading task. The cognitive aspects of information processing were quantified using a memory task. Lastly, motor tasks utilized included a stimulus response task (modified Fitts‟ task) a neural reflex task line tracking task.

In task-related performance the accommodation task did not actually measure accommodation, but rather choice reaction time. The visual detection task measured simple

reaction time, while the final visual perceptual task measured visual processing speed in reading. The memory task quantified an individual‟s memory recall capacity and the motor tasks measured reaction time and line tracking.

Differential analysis in the visual perception tasks looked to quantify resource utilization at the varying stages of information processing. This was achieved by assessing the difference in performance responses between complex and simple trials of each task. The resources measured for the visual perception tasks included, accommodation of the eye, visual object recognition, and visual pattern recognition. The memory task assessed memory capacity and recall. Furthermore, by implementing two different rehearsal periods, the memory task allowed for the quantification of memory recall under conditions of reduced time for rehearsal. The motor tasks assessed motor programming and motor precision as well as fine motor control and afferent neural feedback.

For an in-depth insight into these tasks and the various setting please see subsequent section entitled “instrumentation and measurement of variables”

Dependent variables

Performance parameters

The following performance measures were measured throughout the test battery and varied between the six dependent tests. Reaction time (RT) [milliseconds], target deviation (TD) [millimetres], correct identification of stimuli [% overlooked], error rate [% errors], reading speed [words/minute], driving reaction time, information capacity [bits/second] and steering alternation frequency [1/s], memory recall [% correct] and response delay [seconds].

Physiological parameters

Heart rate frequency (HRF), heart rate variability (rMSSD) and body temperature (BT) were the physiological variables measured during experimentation. All physiological variables were recorded continuously throughout each test battery with the use of a Biometrics Datalogger. This provided four 20- minute recordings of each variable in each experimental session. BT was recorded via electrodes on the skin surface (forehead) and in the ear (tympanic

temperature) of each participant. The heart rate parameters were measured by the Datalogger via a Polar T34 heart rate belt.

Oculomotor parameters

Eye movement analysis included the measurement of saccade speed (SS), saccade amplitude (SA), pupil diameter (PD), blink frequency (FB) and fixation duration (FD). All measures were recorded with the Dikablis Eye Tracking system (see section entitled “Eye motion analysis”).

Control variables

Breath-alcohol concentration

Breath alcohol concentration was measured to confirm that the calculated amount of alcohol ingested induced the correct level of intoxication. Measurements were taken every 20 minutes post alcohol ingestion utilising the Alcoscan AL9000 light breath analyser. This specific unit is a hand held, portable breath alcohol tester with an electrochemical Fuel Cell Sensor. It houses the latest Fuel Cell Sensor Technology providing the best possible accuracy, of ±0.01%BAC at 0.05%BAC. This unit was calibrated before testing and after 1000 samples had been taken.

Experimental conditions

Participants were required to complete four experimental conditions in two testing sessions and these sessions varied only by time of day. The four experimental conditions under investigation varied according to the independent variables under study. These were a baseline test (to establish reference measures on all measured variables) and three test batteries varying in alcohol and caffeine dose and dependent on group. These conditions are outlined below.

- Condition 1: Base line test (BLT).
  All groups: Zero alcohol and caffeine administration (pure baseline measure).

- Condition 2: Test battery 1 (TB1).
  Zero alcohol administration for all groups.
  Caffeine+alcohol group: single dose caffeine consumption (4 mg/kg body weight)

- Condition 3: Test battery 2 (TB2).
  Alcohol group: single dose alcohol consumption (0.4 g/kg)
  Caffeine+alcohol group: single dose alcohol consumption (0.4 g/kg) while under the influence of caffeine administration (4 mg/kg body weight)
  Control group: No administration

- Condition 4: Test battery 3 (TB3).
  Alcohol group: Alcohol administration. (0.4 g/kg)
  Caffeine+alcohol group: Alcohol (0.4 g/kg) and caffeine administration (4 mg/kg body weight)
  Control group: No administration

Participants were requested to perform two experimental sessions, a morning and an evening condition. Experimentation sessions were separated with one week‟s break, and fell on the same day of the week as the first experimental session. This criterion was instated to reduce the effects of the transfer of learning between sessions. The four conditions were repeated in exactly the same fashion for daytime and evening experimentation throughout all participants for each group.

Design matrix

This investigation incorporates a mixed repeated/non-repeated design. Three groups of 36 participants (*n*=108) completed four experimental conditions in two varying sessions; morning and evening. The completion of both morning and evening test sessions - by all groups - represents the repeated factor of the study. The non-repeated aspect of the study involved the utilisation of varying experimental groups (varied by ingestion of alcohol and/or caffeine). The utilisation of the three groups allowed for the comparison of the *control* group to the

alcohol and *caffeine+alcohol* groups, as well as the comparisons between the experimental groups. These interactions can be seen in Table IV.

Table IV: Design Matrix

	BLT	TB1	TB2	TB3
Control	-	-	-	-
Alcohol	-	0.0 mg/L	0.245 mg/L	0.375 mg/L
Caffeine+alcohol	-	0.0 mg/L 4mg/kg	0.245 mg/L 4mg/kg	0.375 mg/L 4mg/kg

The dependent test battery was conducted four times per testing session, BLT, TB1, TB2 and TB3. This allowed for the comparison of BLT measures to three test batteries representing different breath alcohol concentrations, as well as in comparison to breath alcohol concentrations affected by caffeine. All experimental conditions were standardised across both experimental and control groups. The experimental group participants were detained in the laboratory until the breath alcohol concentration reduced to 0.15 mg/L – a breath alcohol concentration level deemed to be safe to perform daily tasks without hazard.

Techniques

A key research technique applied in this analysis was that of a differential approach to test performance.

The differential approach is a method used to ascertain resource allocation and resource loading. The aim of this approach is to understand, on a process by process level, the development of strain over time and how various resources are loaded during task execution (Ngcamu and Göbel, 2011). It involves conducting resource- based tasks that are identical in every manner except for one aspect of the task. By altering this single aspect the researcher aims to determine the effects of that change on overall performance. This principle requires the comparison of pre resource- test measures (BLT) and post resource- test measures (TB1: 0.0, TB2: 0.075% and TB3: 0.05% breath alcohol concentration). Further, this differential design involves testing simple and complex versions of the same task, allowing for

comparison between complexities and between pre- and post- measures. Kahneman (1973) contends that tasks at different levels of complexity elicit different degrees of arousal and demand different amounts of attention and effort. Therefore, by altering the task complexity one can determine the amount of effort required to perform that specific task. According to Ngcamu and Göbel (2011), the rationale for conducting the resource test before is to provide a baseline or reference measure of the resource, which will be compared to the results of the post resource test - conducted under the influence of alcohol.

For this investigation the above approach will allow for the comparison of resources at baseline and at breath alcohol concentrations of 0.0, 0.05% and 0.075% in order to establish the effects of alcohol on resource depletion. Further, comparison of simple versus complex tasks will allow for the comparison of resource allocation. A diagram of this approach can be seen below (Figure 5).

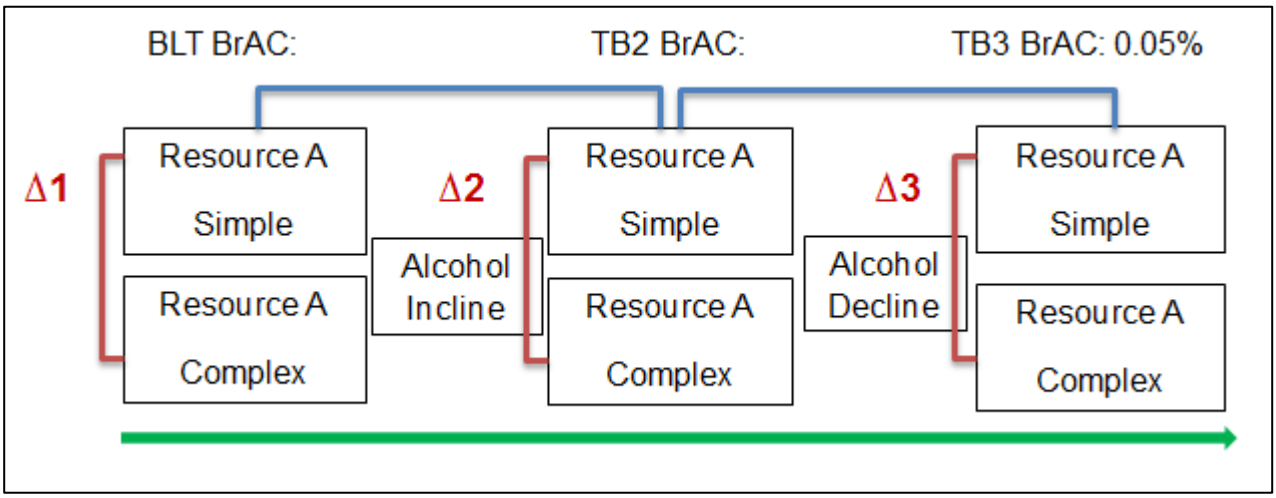

Figure 5: Diagrammatic representation of the differential approach to testing

In order to effectively assess to whether and to what extent performance was varied by the alteration of a single task aspect, comparison of pre-test measures against the varying breath alcohol concentrations as well as between complexities was necessary. If performance resulting from the varied conditions was comparable, then that single aspect (i.e. complexity) did not have an effect. In contrast, if performance of the same task elicited a change in output (i.e. performance is lower under high complexity) then it was concluded that the altered

aspect had an effect on overall performance. With reference to Figure 5, if $\Delta 1$ is equal to $\Delta 2$ and $\Delta 3$ then resource A was not affected by the consumption of alcohol. However, if $\Delta 1$ is not equal to $\Delta 2$ and $\Delta 3$ then resource A was affected purely by the alcohol consumption.

By implementing this design principle, a task can be applied that is differently taxing on the participants‟ visual perception, cognitive or motor resources. This will be observed with the high complexity task requiring greater attention and resource allocation in comparison to the low complexity task, thus yielding greater decrements in performance. This design technique also renders added value by providing information at different complexities, as these may affect the various systems (perceptual, cognitive, motor) differently.

Dependent test protocol

A dependent test battery was designed to analyse the effects of alcohol consumption, the alcohol-caffeine interaction as well as the time of day effects on visual perception, cognitive as well as motor performance. The test battery was designed according to the differential testing approach (see section entitled “Techniques”) which involves testing two complexities of the same tasks, to ascertain how this differential factor taxes the relevant information processing resources. Six dependent tests, two visual perception, two cognitive and two motor tasks, were used to test the proposed research question.

In an attempt to reduce order and learning effects, a permutation table was constructed which ensured that the order of testing was randomised (Appendix C). This table allowed for the equal randomisation of participants and testing conditions, contributing to the reliability of the study. Furthermore, this table ensured equal distribution of participants between testing conditions and session times.

Visual perception performance

Two visual perception tasks were utilised to analyse the perceptual/sensory aspect of human information processing performance. A visual detection task was implemented to test vigilance and object perception and to determine how these variables are affected by the administration of alcohol, as well as how caffeine affects this relationship. A number of studies have been used to assess vigilance under conditions of alcohol consumption and caffeine

ingestion, with many of these having made use of visual detection tasks (Lorist & Snel, 1997; Newton, 2009; Brunyé *et al*., 2010). Research indicates that visual monitoring performance and visual detection decrease under the influence of alcohol (Moskowitz & Fiorentino, 2000); while the opposite is observed in caffeine trials (Newton, 2009; Brunyé *et al*., 2010).

The second visual perception measure - an accommodation task – was used to determine how accommodation of the eye via the ciliary muscles is affected. This task allowed for an overlook of how the visual system is taxed and affected by alcohol, caffeine-alcohol antagonism and time of day. Anderson (2010) found that a similar accommodation task incurred marked changes in saccade speed, pupil diameter and fixation duration, while significant changes were observed in blink frequency. With a change in focus from fatigue to alcohol intoxication, it is hypothesised that this study will find significant changes across all eye parameters. The applied accommodation task is comparable to inspection time tasks. In tasks involving inspection, participants are required to identify subtle changes in stimuli. During these tasks, time (reaction time) is recorded and the final result is termed inspection time. Inspection time tasks have been used to identify early stage information processing performance and have been found to show sensitivity to pharmacological agents (Stough, Managan, Bates, Frank, Kerkin and Pellet, 1995).

A reading task was implemented for visual perception information processing, as this task is representative of object recognition with cognitive processing. It has been stated that word categorisation and word recognition – two tasks that assess complex cognitive processes - are deleteriously affected by the ingestion of alcohol (Tzambazis & Stough, 2000). Maylor *et al*., (1987) contend that alcohol has the ability to decrease performance in word categorisation tasks, but improve and/or impair accurate semantic performance in tasks such as word recognition. The reading task was selected because it is a search- and- select task that possesses a visual-cognitive nature, requiring input from the visual and cognitive systems to detect and recognise spelling errors. Although this task utilises both the visual and cognitive systems, it is considered to be predominantly visually based. Therefore, changes in performance can be attributed to a breakdown in visual recognition ability. Furthermore, this task has proved to be sensitive to changes in complexity (high and low) causing an increase

in performance decrements as a function of time, while physiological measures remained unchanged, (Chaplin, 2010).

These tasks were selected to represent the visual perception aspect of human information processing as they isolate the visual system and require little input from the cognitive and motor resources.

Cognitive performance

A memory/pattern recognition task was utilised to analyse the cognitive aspects of human information processing. This task was implemented to tax the memory system and to determine the interaction with all independent variables. Memory tasks represent higher-order cognitive functioning and have been implemented to test both implicit and explicit aspects of memory under conditions of alcohol intoxication (Lister, Gorenstein, Fisher-Flowers, Weingartner and Eckardt, 1991). These researchers illustrated that alcohol impaired the ability to explicitly remember words, but did not impair memory on the same material when assessed implicitly. Huysamen (2011) observed that a memory recall task (digit span) was sensitive to a change in complexity but not sensitive to a change in time of day. This researcher recorded significant differences in the number of correctly remembered numbers between conditions of high complexity (seven numbers) and low complexity (five numbers), a finding supported by Parker (2011).

Due to the differential nature of this study, memory recall (digit span) will prove to be a beneficial dependent test to assess cognitive functioning under conditions of alcohol ingestion. Furthermore, the combinations of these tasks allow for both simple and higher order cognitive performance to be tested.

Motor performance

With regard to motor output the following tasks were applied. A modified version of the Fitts‟ task (1954) allowed analysis of motor pattern recruitment and precision of movement. This task was utilised as it provides measures for many motor output parameters. Parker (2011) utilised a similar modified stimulus response task and found a substantial increase in target deviation and response time in conditions involving alcohol consumption compared to sober

conditions. This test has also proved to be sensitive to changes in time of day and in complexity (Mahembe, 2010; Huysamen, 2011).

Secondly, a driving simulated lane tracking task was used to measure neural reflex ability. This task was selected for its ability to measure maximal attention and effort of the participant in a driving related task. This measurement is possible through the performance variables calculated by the simulator.

Test battery duration

The duration of the test battery employed was approximately 25 minutes. The six dependent tests conducted each had a variable duration.

Table V: Test battery and task durations

Task	Simple task duration [seconds]	Complex task duration [seconds]
Visual Detection	45	45
Accommodation	60	60
Reading	120	120
Memory	2 x 60 (120)	2 x 90 (180)
Stimulus response	90	90
Driving Simulator	60	60
Duration [minutes]	8.25	9.25
Total duration[minutes]	17.5	

The task that required the most time was the reading task for cognitive performance, lasting 120 seconds. The shortest test duration was the accommodation task lasting 45 seconds, while average task duration approximated 90 seconds. In order to be realistic, 30 minutes was allocated for the test battery, allowing for changing between tasks and to allow for experimental setup for each participant. As previously stated the test battery was conducted four times in each experimental session.

Chronobiology and chronotype

To aid in data interpretation, the chronotype of each individual had to be established. To do this, each participant was required to complete a morningness-eveningness questionnaire (Horne and Östberg, 1976). This provided valuable information regarding when each individual would experience peaks and nadirs in each respective circadian rhythm. This questionnaire classified individuals on the following levels according to the total scores obtained;

1. Definitely morning type 70 - 83
2. Moderately morning type 56 - 69
3. Neither type 42 - 55
4. Moderately evening type 28 - 41
5. Definitely evening type 14 – 27

Statistical analyses were run on the participants‟ chronobiology to ensure an equal distribution of chronotypes was present. Analysis revealed that no significant group differences in questionnaire scores were demonstrated. Two female participants fell within the “definitely morning-type” and “definitely evening-type” groups (one in each group respectively) on the Morningness-Eveningness questionnaire, with the majority of subjects falling into the “neither” chronotype category (42 – 45): the rest fell within the “moderate” categories. The groups were therefore normally distributed in terms of chronobiology, and this factor should not confound the results of this investigation.

INSTRUMENTATION AND MEASUREMENT OF VARIABLES

Experimental tasks

Accommodation Task

An accommodation task was implemented to test the perceptual aspects of the information processing stream. The accommodation task implemented was based on the works of Anderson (2010), who utilised a similar task to test the fatiguing effect of sustained

convergence and accommodation of the ocular motor system. For the purpose of this study, Anderson‟s accommodation task was adapted to test the effect of changing convergence and accommodation on the perceptual system under conditions of alcohol ingestion.

The accommodation task utilised in this study required participants to identify a stimulus (4 x 4 mm white square on a black background) in both static and dynamic accommodation scenarios. The stimulus contained a smaller black dot within the white dot – either on the left or the right side – and required participants to left click or right click the mouse to identify in which direction the smaller black dot was appearing (Figure 6).

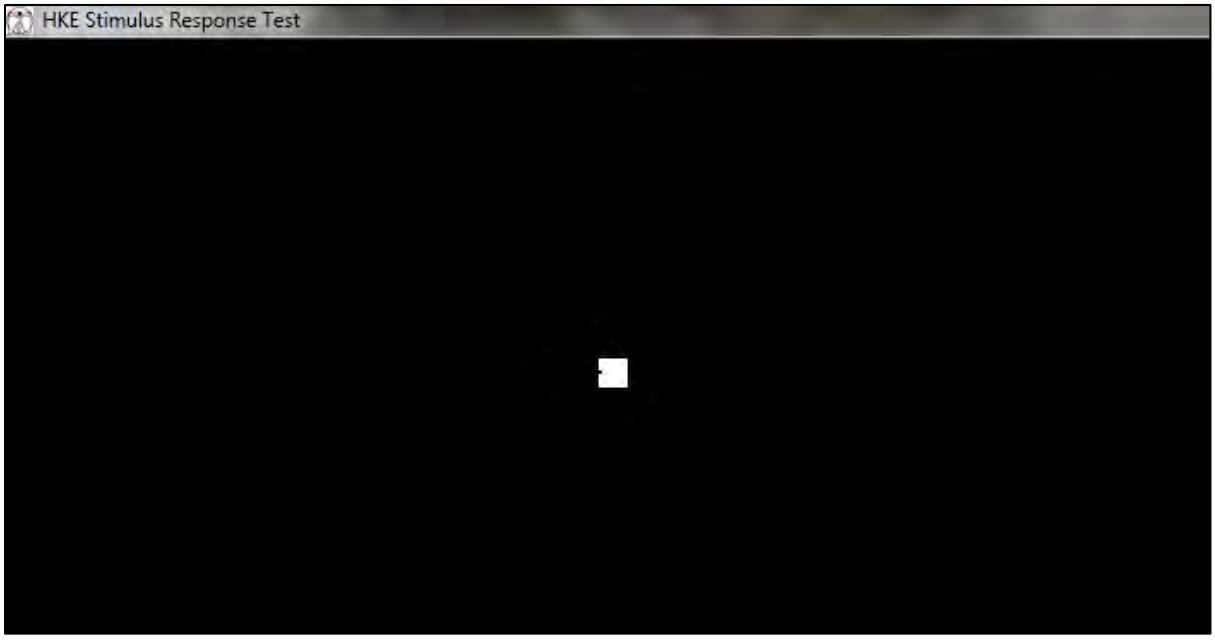

Figure 6: Accommodation task (Stimulus identification and accommodation).

The static accommodation condition required participants to identify the stimulus appearing randomly on a screen positioned 200 cm away from the participant. In the dynamic accommodation condition, the stimuli would alternate randomly between a screen positioned closer to the participant (40 cm) and the further (200 cm) screen. Task duration for simple and complex tasks was standardised to 60 seconds. Static and dynamic aspects of this task were conducted for the purpose of the differential testing approach. However the static condition when compared to the dynamic condition, further allowed for the quantification of visual workload incurred when performing the dynamic condition.

Visual Detection Task

The visual detection task implemented in this study was used to tax the visual system while simultaneously measuring stimulus recognition and vigilance. The objective of this task was to differentiate one red stimulus among numerous white stimuli moving in random directions from one another (divergent perspective). The simple and complex aspects of the task varied according to the number of white stimuli present, 40 and 80 respectively. The size of all stimuli was set at 2 mm x 2 mm and all were shaped in the form of stars. The participant was required to respond to the critical stimulus (red star) with a critical response (left mouse button click) as soon as the critical stimulus was observed. The critical stimulus would appear in varying spatial orientations on the screen at random intervals between 300 and 1000 ms.

Figure 7: Visual detection task (Stimulus recognition and vigilance).

The task was displayed on a 23” HP T230i Wide LCD monitor. This large screen was selected so that both peripheral and centralised aspects of vision could be tested. Further, the viewing distance between the screen and the participant‟s eyes was standardised for each participant to 50 cm. Task duration was set at 90 seconds, and subjects were required to remain the standardised distance from the screen to ensure viewing distance was not a confounding variable.

Reading Task

The reading task implemented in this study was based on the work conducted by Chaplin (2010) and made use of four reading texts – allowing for new material to be read in the different experimental sessions. The reading material covered similar topics and was amended to make it more relevant to this study. Colloquially written, South African- related news, health and lifestyle texts were selected for this task to ensure each individual would have an understanding of what was presented. The texts were scanned into the computer and then converted to a Microsoft word document. Once converted, obvious typing errors were made within the text (double letters), and served as the stimuli to be identified during this task. The errors within the text were to a small extent content related which ensured participants read the text and did not merely scan for errors. This document was then saved as 300 dpi (high resolution) and 60 dpi (low resolution) versions. The format of the text was constant between both conditions: Times New Roman font, with a 12 pt. font size as well as justified columns and 1.15 line spacing.

Participants were required to be seated at a desk, with the text displayed in front of the participant at a predetermined reading distance (50 cm). This set-up was kept constant for both reading trials and across all participant testing conditions. The reading task required participants to read the texts silently and to circle the errors (double letters in certain words [I.e. bookk]) that were found. Each simple (300 dpi) and complex (60 dpi) test was run for 120 seconds and participants were required to mark on the text how much of the text was read, allowing performance measures of reading speed [words/minute] and errors overlook [% missed] to be measured. The texts were randomized between control and experimental groups for both the high and low resolution texts. This was done to ensure no learning effect was present and that the difference between variables was a function of the text employed. The error rate within each text was constant and amounted to an error every 20 words [5 errors/100 words].

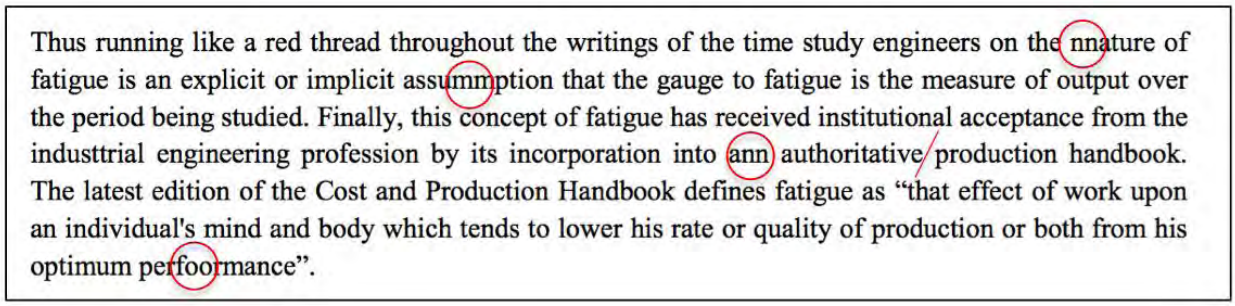

Figure 8: High resolution reading text

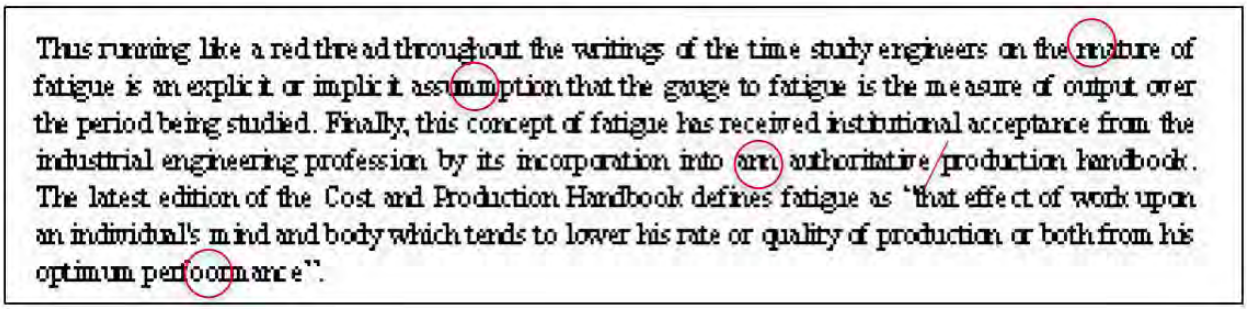

Figure 9: Low resolution reading text

PEBL Memory (digit span) Task

The memory task implemented in this study was a memory recall task (digit span). This task has been used in previous research to measure working memory (Wetherill & Fromme, 2011) as well as perceptual-motor processing speed (Brumback *et al*., 2007). The memory recall task is an automated computer memory test which presents auditory and visual stimuli in the form of numbers in a sequence. The participant is then required to remember and rehash the sequence of numbers by keying in the numbers using the numeric keys on a standard QWERTY keyboard. This memory test was adapted from the works of PEBL the psychological test battery (Mueller, 2010). The basic PEBL test begins with a sequence of four numbers. Each time the participant remembers the sequence correctly, the sequence increases by one unit (Mueller, 2010). When the participant incorrectly rehashes the sequence, the following sequence will be reduced by one unit. This process will carry on until the end of the allocated test time.

The memory test employed in this study was adapted to suit the controlled nature of the differential testing approach. This memory task was adapted in two respects, focusing on the effects of alcohol on memory capacity (five vs. seven number chunking) and rehearsal period (short vs. long term rehearsal). Therefore, the number of digits in the sequence was adjusted to five (low complexity) and seven (high complexity) chunks respectively. The number of chunks to utilise was selected on the basis of the average memory capacity of each individual, being 5 ± 2 (Miller, 1956). Five and seven number chunking would then reflect the average chunking capacity of average individuals. With respect to short and long term rehearsal, the time between the stimulus and the expected response was adapted. A rehearsal time of two and four seconds between stimulus and response was implemented for the low and high complexity trials respectively. Test durations of 60 and 90 seconds respectively were employed for low and high rehearsal complexity trials, in combination with five and seven numbers. Therefore, four tests were run per condition; 5-60 (chunks-test duration), 5-90, 7-60 and 7-90. Each participant was required to correctly rehash the sequence of numbers immediately after the rehearsal elapsed and to confirm the input with the enter key. These experimental changes were effected by the principal researcher, by reprogramming the memory task files. Task duration, number of chunks and rehearsal time were amended to effect these changes.

Set-up of the task required each participant to be seated in front of a computer at a standardised 50 cm distance from the screen. Participants were asked to keep both hands on the keyboard to reduce the amount of movement and thus reduce factors affecting response time. The modified PBEL software recorded all relevant performance variables, which included; error rate [% correct], response duration [seconds] and response delay [seconds].

Stimulus Response Task

A stimulus response test (SRT) based on the Fitt"s task (Fitts, 1954) was used in this study to test motor programming and motor precision. In this version of the SRT both simple and complex conditions were amalgamated into one testing scenario. The modified SRT required participants to respond to stimuli (green dot on a black screen) by touching the stimulus on a Hewlett Packard (HP) 23" LCD touchscreen in the shortest time possible (Figure 10).

As observed in Figure 10, one of four stimuli would appear (one at a time) on a screen (dimension 550 x 290 mm). Each stimulus was set to be presented in four varying scenarios, dictated by the position of stimulus – and size of stimulus; central-large (1) ,anywhere-large (2), central-small (3) and anywhere-small (4). In scenarios of central-large (1) and central-small (3) a stimulus (a dot of 24 mm and 12 mm respectively) would appear in the centre of the screen. Conversely, in scenarios of anywhere-large (2) and anywhere-small (4) the stimulus (a dot of 24 mm and 12 mm respectively) would appear anywhere on the screen, but at least 5 cm from the centre point. The order of stimuli was alternated so that the every second stimulus would appear on the centre of the screen

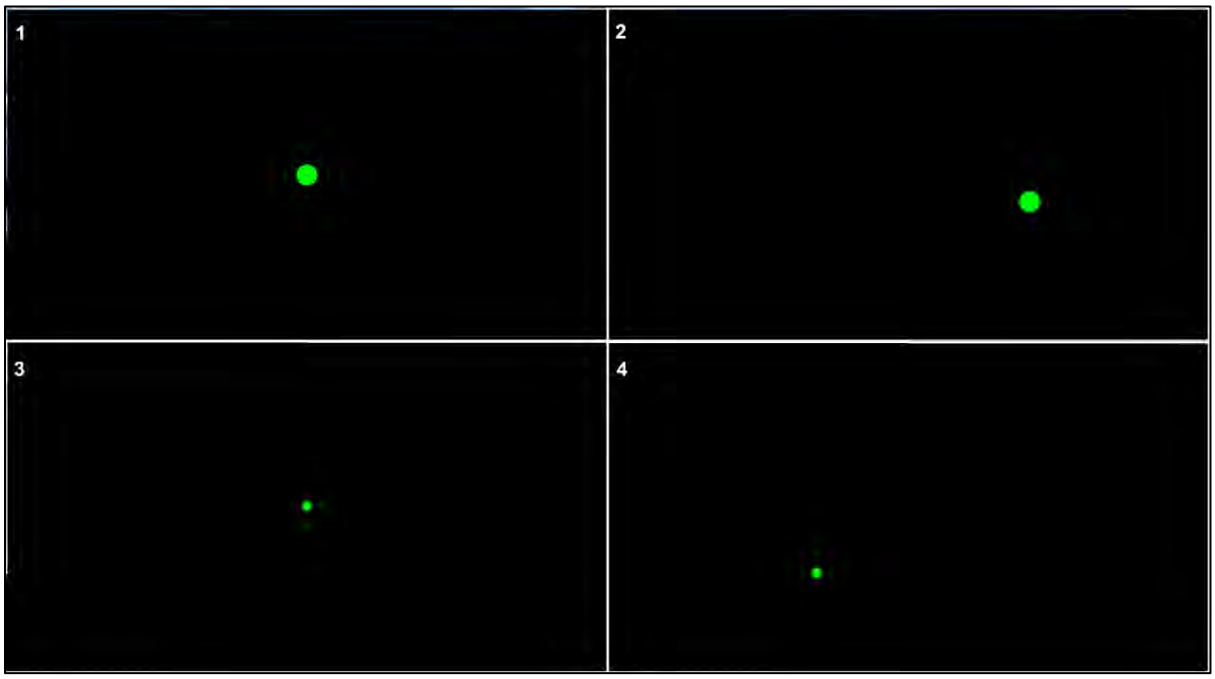

Figure 10: Stimulus response task setup (sequencing).

The concept behind this task set up is as follows; from the habituation session, participants would realise that every second stimulus would appear in the centre of the screen, and could therefore anticipate the stimulus. This anticipation would result in pre-motor programming for the required response. In scenarios where the stimulus appears at random locations on the screen („anywhere"), the motor programming cannot be anticipated; the participant must wait for presentation of the stimulus before the required motor programming can be produced. Therefore, the motor programming time of each participant could be measured by the time

taken between „central" and „anywhere" stimuli. Similarly, the difference in size of the respective stimuli, allow for motor precision to be measured; with a small (12 mm) stimulus requiring more precise motor precision.

The duration of this test was set to 90 seconds with a new stimulus appearing once the previous stimulus had been touched. The time taken to respond to the stimulus from central to anywhere was defined as the time taken to program a motor response whereas the time take to move from anywhere to central was considered to be a motor response time. Motor precision was measured by the accuracy with which each individual touched the centre of the stimulus.

Participants were required to remain seated at a distance of 50 cm in front of a touch screen while completing the SRT. Furthermore, participants were instructed to use only the dominant hand to respond to the stimulus and to hover the hand in the same area of the screen once the stimulus had been responded to. This was done to ensure response time and motor programming time was not adversely affected. Performance variables under study were recorded by the SRT software and included reaction time [seconds] and target deviation [mm].

Neural Reflex Task

A driving simulator task was implement as the second motor task, and was set up to test the neural reflex ability of the subjects" motor control. In this task, subjects were required to use a driving simulator to track a white line in the centre of the constructed road (Figure 11). Task setup ensured that driving speed, street width and curve radius were all kept constant for both conditions. In this task, steering sensitivity was the variable to be manipulated and as a result two conditions were tested, high sensitivity (1.25) and low sensitivity (0.5) respectively. These conditions require low proprioceptive and high proprioceptive control, to perform the task.

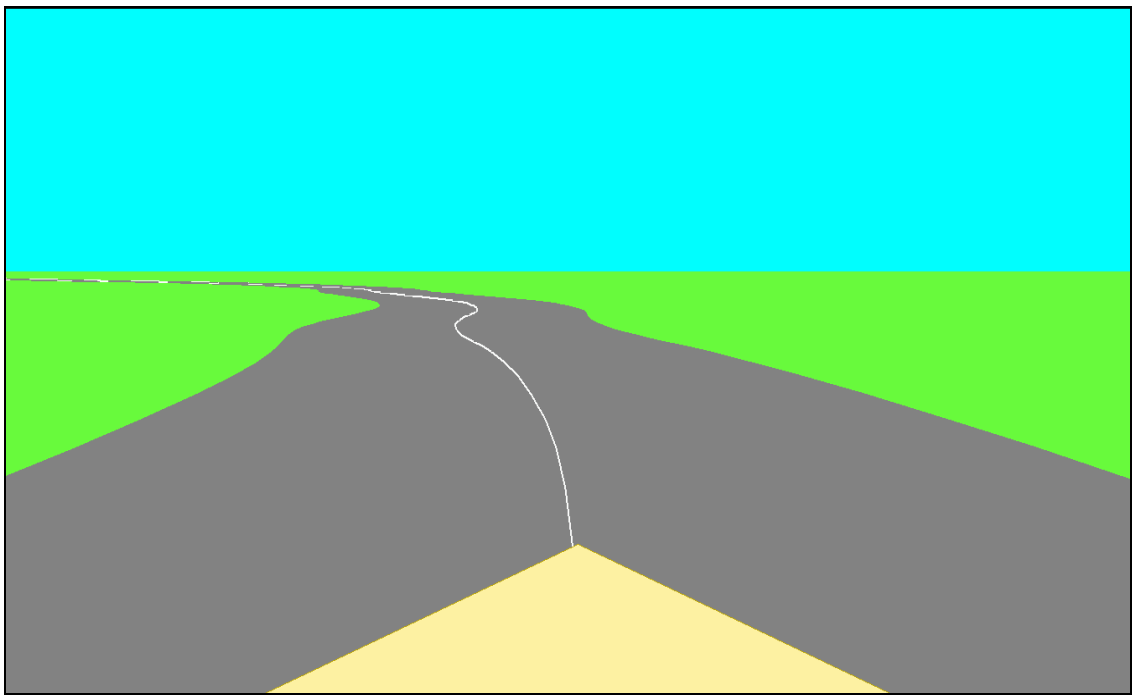

Figure 11: Representation of the neural reflex task.

Viewing distance of the simulator was 60 cm and was displayed on a 19 inch LCD monitor. The steering wheel was the input tool for this task and was adapted and constructed from a semi-professional gaming steering wheel, within the department of Human Kinetics and Ergonomics. The steering wheel was connected to the computer via a USB mouse driver where steering wheel movements mimicked horizontal mouse movements. Feedback was provided if the participant left the road. This feedback was the shaking of the picture (to mimic a car shaking) until the yellow triangle was back on the road. It should be noted that the steering wheel used was selected based on the fact that it was robust (as a normal car steering wheel should be) and that it provided no feedback to the participant. The performance variables as measured by the neural reflex task are defined as follows;

- *Mean deviation* calculated the average deviation from the target line [meters].
- *Reaction time* produced the effective reaction delay [seconds], taking into account both the deviation from target line as well as the amplitude and frequency of the deviation from the target line. This parameter was therefore independent of the driving speed and the curvature of the line.

- *Information Capacity* is the Log^2 of the reciprocal value of the reaction delay, expressed as an information processing capacity [bit/s].
- *Steering alteration frequency* considers the alteration frequency of vehicle control by measuring oscillation frequency [1/s].

Experimental Instrumentation

The following equipment was utilised in the experimentation sessions to record the various dependent variables under study. The equipment utilised throughout experimentation and for each participant was standardised in an attempt to increase the reproducibility and reliability of the data.

Biometrics Datalogger

A Biometrics 4WX8 Datalogger was used to capture the various heart rate parameters as well as body temperature (tympanic and skin).

PEBL Memory (digit span) Test Software

The PEBL DSST (version 0.11) was implemented to conduct the memory recall test. The test was obtained from the PEBL Psychological Test Battery Version 0.5 (http://pebl.sourceforge.net/battery.html). This software included the program launcher as well as the various PBEL setup files that were amended for this study. This was a standard digit span task with both auditory and visual presentation.

Stimulus Response Software

The in-house Stimulus Response Software utilised by the Human Kinetics and Ergonomics Department at Rhodes University (© Göbel 2010-2012) was implemented to run the modified Stimulus Response Task as well as the Accommodation, Visual Detection and Neural Reflex tasks. The dependent tests were modified to suit the aims of this study by amending the setup settings within each program.

Heart Rate and Heart Rate Variability

Heart rate variability is the variability in the interval between consecutive heartbeats (Lin, Imamiya & Mao, 2008). For the purpose of this investigation, heart rate variability, a

physiological parameter, was used to infer cognitive workload, as suggested by a variety of authors (Rowe *et al*., 1998; Luft *et al*., 2009; Huysamen, 2011). Analysis methods of heart rate variability include both the time-domain and frequency-domain analyses (Jorna, 1992).

A Polar T34 heart rate belt was used to record cardiac responses during each experimental session. The electrode strap was placed around the mid-chest, at the inferior border of the pectoralis major muscle in line with the apex of the left ventricle. Conductive gel was applied to the electrode sensors to reduce the loss of signal caused by lack of moisture, or friction between the electrodes and skin. All data was transferred via Bluetooth to a Biometrics Datalogger, where all data were stored and saved for further analysis.

The Biometrics Datalogger in conjunction with the T34 belt allowed for a detailed beat-to-beat analysis, and also provided R-R intervals and ratios which are important for the calculation of heart rate variability parameters. Heart rate frequency was calculated from the inter-beat-interval. The data were filtered by accepting a minimum heart rate of 40 $bt.min^{-1}$ and a maximum of 140 $bt.min^{-1}$. The maximum variation between beats was set to 200%.

Time-domain analyses

There are a number of different time-domain analyses that can be performed. This study measured four different analyses, namely SDNN, RMSSD, PNN50, and the PNN30 (an altered version of the PNN50). SDNN refers to the mean difference between all adjacent beat-to-beat (N-N) intervals, while RMSSD calculates the square root of the mean of the sum of squares differences between adjacent N-N intervals. The PNN50 evaluates the percentage of adjacent N-N intervals that differed by more than 50 ms compared to the total N-N interval. PNN30 is calculated identically to the PNN50, using 30 ms as the differentiation criteria – this variable was constructed in order to improve identification of phases with lower variability.

The interval length for time-domain analyses was set to 120 s – the duration of the longest interval from all dependent tests.

Frequency-domain analyses

Frequency-domain analyses decompose the HRV signal into separate frequency ranges. The most widely used - in the case of mental workload - being high frequency (0.15-0.4 Hz) and

low frequency (0.04-0.15 Hz) (Jorna, 1992). The low frequency spectrum is thought to reflect sympathetic modulation/activity and high frequency to reflect vagal/parasympathetic activation and respiration (Berntson *et al*., 1997). This study analysed both high frequency and low frequency spectra, which were calculated using the Fourier transformation (FFT). For each frequency band both the total power and the centre frequency were calculated – the power variable reflects the total power within the band in ms^2, while the centre frequency considers the frequency at which the power spectrum is split into two portions of equal power (Hz).

The ratio between low and high frequency has also been suggested by various authors to reflect sympathetic modulations (Miyake, 2001; Lin *et al*., 2008). For this analysis, the percentage of the low frequency component relative to the total (LF+HF) power was also calculated.

Eye Motion Analysis

The Dikablis eye tracker unit consists of three sub-units; the head unit, receiver and recorder. The head unit consists of the forehead device, the camera mount which has a nose support and the two cameras (J. Robertson, 2009).Once placed on the head, the eye camera is located above the left cheek and is directed toward the left eye - this camera detects the cornea reflex and identifies the pupil. The field camera (located superiorly to the nose) records the field of view of the participant, and is the second camera on the head unit. The second unit (Dikablis wireless receiver) receives the information from the head unit and transmits this information to the recorder, where it is captured and stored by the Dikablis software (Lange, Wohlfarter and Bubb, 2006).

Figure 12: The Dikablis eye tracking head unit

The Dikablis eye tracker is a wireless unit that does not restrict any range of motion of the head or movement of the body. The unit attaches to the participant via an elastic head strap and is supported on the nose with a nose support piece. This attachment keeps the unit stable on the head and allows for reliable recording of eye movements as well as the participant‟s field of view. It should be noted that testing was conducted in a light- controlled room to reduce any effects of light on pupil size and other oculomotor parameters. The eye movements analysed in this study included pupil size, fixation duration and saccade speed, saccade amplitude and blink frequency.

Pupil diameter

The pupil size variable measured by the area of the Dikablis system was used to calculate pupil diameter, as this was found to be the most robust of the available measures (compared to pupil width or height only). A dynamic pupil filter was utilised in order to exclude any change in pupil size greater than 20% per 100 ms period.

Blink frequency and duration

When considering blink duration and frequency, an eye blink filter was set with a minimum duration of 80 ms, a maximum duration of 1000 ms and with a minimum and maximum

frequency of 3 to 30 blinks per minute, respectively. Blink frequency was calculated as the number of blinks per one minute interval [blinks/minute], and blink duration was calculated as the average duration [milliseconds] over the same time interval.

Fixation duration

Fixations were defined by as eye movements that were not faster than 5^{o}/s and between 100 and 1000 ms duration. This filter was implemented for the consideration of pursuit movements and noise detection of the eye tracking system. Average fixation duration was the main measure of fixation and was measured in [seconds].

Saccades

Saccades were defined as movements above the threshold of 10^{o}/s. While saccades typically occur at a much greater speed, the lower threshold was considered more suitable due to the low pass filter function caused by the 50 Hz temporal resolution of the Dikablis system. Mean saccade speed and amplitude were calculated for each one minute interval, and were measured in [^{0}/second] and [^{0}] respectively.

Additional Equipment

In addition to the above mentioned equipment, desktop and laptop computers were utilised to run the accommodation, memory, stimulus response, driving simulator and visual detection tasks and the accompanying software. A HP 2310Ti 23" Wide LCD Touchscreen was used to conduct the SRT while a Liesegang DV 455 projector was used to display the accommodation task on a standard overhead white screen. The reading texts can be regarded as equipment needed to conduct the reading task.

PILOT TESTING

The purpose of the pilot studies was for method optimization and to ensure that any validity drawbacks were rectified.

Pilot test 1

The first pilot test to be conducted was implemented to ascertain the amount variance between a repeated measures bout and non-repeated measures bout on the stimulus

response task. Neither alcohol nor caffeine was administered in this pilot. The aim of this pilot was simply to determine the degree of variance obtained between repeated and non-repeated bouts of the task. This pilot recruited six participants. Five participants were recruited for the non-repeated trial whereas one participant was recruited for the repeated measures trial. In the non-repeated trial, each of the five participants completed one trial of the stimulus response task. The variance obtained from these five trials was then compared to variance obtained from the repeated measures trials. The pilot measured response time, target deviation, heart rate and a variety of heart rate variability parameters. The pilot verified that the variance obtained in the repeated measures was less than that of the non-repeated measures. The amount of variability between trials however, was considered to be normal. In an attempt to reduce the amount of inter-participant variability, it was decided to implement a mixed repeated/non-repeated measures design for this study.

Pilot test 2

The second set of pilot testing investigated the time course of the inclining and declining phases of the blood alcohol curve, based on the Widmark equation. Once the equation had been finalised and the amount of alcohol converted to millilitres of 40% vodka, pilot testing commenced. In this second pilot, eight students (four female and 4 male) from the department of Human Kinetics and Ergonomics were recruited. These individuals were administered a single dose of vodka and water according to the tables defined by the equation calculated (Appendix C). Once the alcohol had been administered, breath alcohol concentration was recorded every 15 minutes for 90 minutes; the results are displayed in Figure 13.

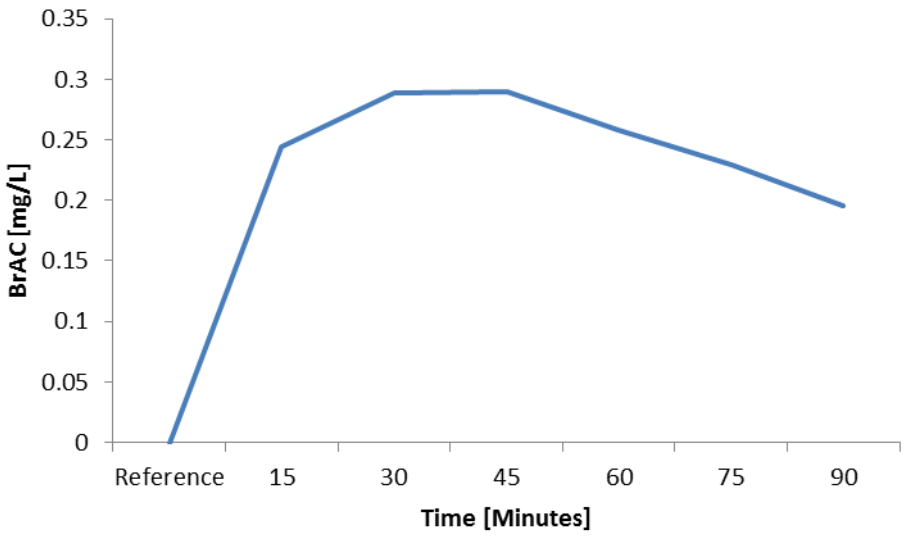

Figure 13: Average time course of breath alcohol concentration (n=8) – Pilot test

The doses administered were intended to effect a maximum breath alcohol concentration of 0.075% (0.375 mg/L); however this was not the result. As demonstrated (Figure 13), peak breath alcohol concentration occurred between 30 and 45 minutes post ingestion. This finding is supported by the work of (Friel *et al*., 1995; Liguori & Robinson, 2001; Vogel-sprott *et al*., 2006; Brumback *et al*., 2007; Fillmore *et al*., 2009). However on average, the maximum breath alcohol concentration effected was marginally below 0.300 mg/L. This pilot delivered important findings. Firstly, peak alcohol concentration occurred between 30 and 45 minutes and secondly, the Widmark equation under- predicted breath alcohol concentration by approximately 20%.

This pilot was imperative in establishing the time course of the experimental session. It was determined that alcohol would be administered approximately 25 minutes before the participant completed the first test under the influence of alcohol - this would ensure the participant would be tested on the inclining phase of alcohol intoxication. Despite the under-prediction of the required breath alcohol concentration, the study moved forward as planned. The principal researcher made this decision based on the fact that the Widmark equation was the only scientifically- based method available to administer alcohol in a reliable fashion.

ETHICAL CONSIDERATIONS

Informed Consent

Before the onset of testing each participant was required to sign an informed consent form. This confirmed that each participant was familiar with the testing procedures and inherent risks associated with this alcohol study. This form ensured that the researcher and the Department of Human Kinetics and Ergonomics would not be held accountable for any injury, harm or illness that arose from the study. Consent also confirmed that each individual was aware that performance and physiological data was recorded and used for statistical analysis.

Privacy and anonymity of results

Information obtained during experimentation was kept confidential and at no stage or time was any participant"s information publicised. The data that was collected during the experimental protocol was used only for statistical analysis. Furthermore, one copy of the data has been kept in the Human Kinetics and Ergonomics department and may be used for teaching or research purposes. However, if data is used for teaching purposes, anonymity was still ensured by replacing participant names with a unique participant testing code.

PARTICIPANT CHARACTERISTICS

Three groups of 36 (n=108), participants were recruited for this alcohol trial. The groups were evenly divided between male and female participants with the age distribution ranging from 20 - 30 years of age. The average age of the cohort was 22.2 ± 2.2 years old. A pre-screening process was implemented before the onset of experimentation in an attempt to recruit a cohort of individuals who were homogenous. Pre-screening required participants to answer three questionnaires (Appendix A) to determine relative alcohol familiarity & tolerance, chronobiology and average caffeine consumption. The pre-screening process ensured that the final sample of participants were homogenous in terms of age, mass, stature, resting heart rate (RHR) body mass index, drinking status, caffeine consumption and chronobiology. Participant mass was not controlled; however, this was measured and used to determine the appropriate quantity of alcohol needed for each individual to reach 0.05% (0.245 mg/L) and

0.075 % (0.375 mg/L) breath alcohol concentration (as per the Equation 1). The average mass of the sample amounted to (72.22 ± 14.21).

The results of the alcohol familiarity and tolerance to alcohol, morningness-eveningness (chronobiology) and caffeine consumption questionnaires are displayed below (Table VI and Table VII), Table VI displaying the results of the male participants and Table VII that of the female participants.

Table VI: Male screening questionnaire results.

	Control		***Alcohol***		***Caffeine+alcohol***	
	(Mean ± SD)	**CV**	**(Mean ± SD)**	**CV**	**(Mean ± SD)**	**CV**
Drink familiarity and tolerance [/40]	(18.38 ± 8.89)	48%	(21.83 ± 3.34)	15%	(21.16 ± 3.82)	18%
Morningness-eveningness [/83]	(52.38 ± 7.85)	15%	(54.5 ± 6.99)	13%	(53.72 ± 9.12)	17%
Caffeine consumption [mg/day]	(332.22 ± 222.79)	67%	(296.11 ± 311.88)	105%	(363.05 ± 94.73)	26%

Table VII: Female screening questionnaire results.

	Control		***Alcohol***		***Caffeine+alcohol***	
	(Mean ± SD)	**CV**	**(Mean ± SD)**	**CV**	**(Mean ± SD)**	**CV**
Drink familiarity and tolerance [/40]	(14.01 ± 8.86)	63%	(16.88 ± 2.34)	12%	(17.66 ± 3.32)	19%
Morningness-eveningness [/83]	(56.05 ± 11.67)	21%	(50.94 ± 9.52)	21%	(55.61 ± 7.96)	14%
Caffeine consumption [mg/day]	(381.38 ± 314.25)	82%	(342.77 ± 214.73)	100%	(357.5 ± 89.21)	25%

Statistical analyses were run on the above variables to determine if any significant group effects were present in the above data. A one-way analysis of variance for each variable confirmed that no significant differences ($p<0.05$) were present within and between groups. Therefore, despite the large coefficient of variation (CV), all groups were deemed to be homogenous.

Participant anthropometric data too was recorded in the pre-screening sessions that took place. These data are displayed in the tables that follow; Table VIII displays male anthropometric data while Table IX displays that for female participants.

Table VIII: Male anthropometric data.

	Control		Alcohol		Caffeine+alcohol	
	(Mean ± SD)	**CV**	**(Mean ± SD)**	**CV**	**(Mean ± SD)**	**CV**
Age (years)	(22.11 ± 1.75)	8%	(22.44 ± 1.62)	7%	(22.72 ± 2.85)	13%
Mass (Kg)	(82.40 ± 8.04)	10%	(82.09 ± 14.03)	17%	(81.43 ± 13.62)	17%
Stature (m)	(1.82 ± 0.05)	3%	(1.81 ± 0.09)	5%	(1.79 ± 0.07)	4%
RHR ($bt.min^{-1}$)	(67.83 ± 8.63)	13%	(75.66 ± 14.46)	19%	(72.55 ± 10.90)	15%
BMI (kg/m^2)	(24.62 ± 1.96)	8%	(24.78 ± 3.66)	15%	(25.18 ± 3.53)	14%

Table IX: Female anthropometric data.

	Control		Alcohol		Caffeine+alcohol	
	(Mean ± SD)	**CV**	**(Mean ± SD)**	**CV**	**(Mean ± SD)**	**CV**
Age (years)	(22.11 ± 2.05)	9%	(22 ± 2.43)	11%	(21.83 ± 2.36)	11%
Mass (Kg)	(64.48 ± 9.71)	15%	(61.94 ± 6.37)	11%	(60.47 ± 6.86)	11%
Stature (m)	(1.64 ± 0.09)	6%	(1.66 ± 0.06)	4%	(1.66 ± 0.05)	3%
RHR ($bt.min^{-1}$)	(76.61 ± 15.35)	20%	(71.33 ± 11.10)	16%	(74.23 ± 11.66)	16%
BMI (kg/m^2)	(23.87 ± 3.78)	16%	(22.44 ± 1.95)	9%	(21.84 ± 2.52)	12%

Statistical analysis of the anthropometric data revealed that there were no significant ($p<0.05$) differences between and within the control and experimental groups. The groups selected for this study are therefore thought to be homogenous and free from extraneous anthropometric influences.

It was important that no participant at the time of study was under the influence of prescription medication and/or over the counter medication or any other drugs and or stimulants as this may be a compounding factor on participant safety and level of inebriation. If this were the case, participants were excluded based on this criterion. A further exclusion

criterion was whether or not a participant falls within the binge drinker category (i.e. 4-5 drinks within 2 hours on any given night out) as this too will affect the level of inebriation. Prior to all sessions participants were requested to abstain from heavy physical activity, smoking, from drinking alcohol and caffeine-containing beverages for at least 24 h, and from eating three hours before testing. Furthermore participants were told to refrain from drinking large amounts of water, as this too would affect the level of inebriation.

EXPERIMENTAL PROCEDURE

Pre-screening and habituation session

Upon arrival at the physiology laboratory at the Department of Human Kinetics and Ergonomics, prospective participants were briefed on the purpose and aims of the study as well as the details of each testing procedure. Following the explanation of the purpose and aims, the individuals were given the opportunity to ask questions concerning the study. Thereafter, the individuals were introduced to the equipment that was to be utilised during experimentation, and were informed about what each device measured and how it was measured. A letter of information regarding the study was issued to each individual - this was done to ensure that each individual fully understood the testing procedure and what was required of him or her. Once the letter had been read and understood, individuals were asked to sign an informed consent form giving permission for the principal researcher and research assistant to record and capture anthropometric data, and if selected for the investigation, to use the participant‟s data in this investigation. It must be noted that informed consent was obtained both verbally and in writing.

Following this, heart rate monitor memory straps were fitted to each participant, and individuals were requested to be seated. Thereafter the prospective participants were requested to fill out three questionnaires; one pertaining to alcohol familiarity and tolerance to alcohol, a second on chronobiology and the last regarding caffeine consumption. During this time the principal researcher noted each individual‟s resting heart rate – this was recorded once the participant had completed the questionnaires. Thereafter, stature and mass were recorded. Individuals were then introduced to each of the six tests that were going to be conducted during experimentation. Participants were informed of what was expected of them

during each of the tests and what was prohibited during experimentation. Thereafter, each individual was required to run each task until they felt comfortable with the task and understood its dynamics. A minimum of three test trials of each task was instated to ensure a thorough habituation to the task. Participants were instructed to refrain from drinking alcohol and caffeine-containing beverages for at least 24 hours before the day of experimentation. Similarly, the prospective participants were requested to eat approximately four hours prior to testing and to refrain from eating for three hours before testing. Other pre-test instructions were also discussed thereafter (appendix B). The pre-screening session was not longer than 40 minutes.

Participants were selected based on the results that were obtained from the screening questionnaires and anthropometric data. Once selected, prospective participants were contacted and experimentation began.

Experimental sessions

Participants returned for the experimental sessions within two weeks of the introductory session. In this session participants were reminded of the purpose and testing procedure before the fitment of the heart rate monitor, body temperature electrodes and eye tracker. Once connected to the relevant equipment, BLT measures were conducted to obtain a 0.0% breath alcohol concentration and 0 mg/kg caffeine ingestion test value. These BLT measures included a breathalyser test to ensure that at the onset of testing no participant was under the influence of alcohol. Depending on the experimental condition, the order of ingestion of caffeine or alcohol was amended accordingly.

In conditions involving alcohol and caffeine ingestion (*caffeine+alcohol* group), the caffeine capsule(s) was/were administered directly after the completion of the BLT and 25 minutes before the initiation of TB1. In experimental conditions involving only alcohol consumption and control, the BLT and TB1 were conducted with no administration of alcohol or caffeine. The same rest interval was implemented across all groups. For the experimental groups, alcohol was administered after the completion of TB1. Once alcohol had been administered, participants waited a further 25 minutes before TB2 was conducted. During this 25 minute period, the principal researcher tested the second participant present at the trial. By this stage

(beginning TB2) breath alcohol concentration was reaching peak concentration. The level of breath alcohol concentration was monitored by conducting breath-alcohol analysis every 20 minutes with the use of a handheld breathalyser. After completion of TB2, the final rest break of 25 minutes was instated and finally TB3 was conducted. It should be noted that participants were tested inter-changeably between conditions. Average time for each condition was approximately 23 minutes, which included the fitment of electrodes and calibration of the eye tracker. Total experimentation time was approximately 2 hr. 45 min. and participants were only permitted to leave the test venue once the breath alcohol concentration had declined to 0.03% (0.15 mg/L).

STATISTICAL HYPOTHESES AND ANALYSIS

Statistical hypothesis

The statistical hypotheses proposed are that the results obtained from the alcohol and non-alcohol conditions will be significantly different from each other in terms of perceptual, cognitive and motor responses. In addition, the results obtained from the morning conditions will be significantly different from those of the evening conditions. Additionally, the perceptual, cognitive and motor response results obtained from conditions with caffeine will be significantly different to conditions without caffeine. Lastly, the results obtained in the next day condition will be significantly different to those of the control group

Hypothesis 1: Perceptual, cognitive and sensory-motor performance are equal for both non-alcohol and alcohol conditions.

H_o: $\mu R_{i,\ ii,\ iii}\ NA = \mu R_{i,\ ii,\ iii}\ A$

H_a: $\mu R_{i,\ ii,\ iii}\ NA \neq \mu R_{i,\ ii,\ iii}\ A$

Where: NA = Non-alcohol conditions

A = Alcohol consumption conditions

R = Responses (Performance, Physiological and Oculomotor parameters)

i = Perceptual

ii = Cognitive

iii = Motor

Hypothesis 2: Perceptual, cognitive and sensory-motor performance are equal for both non-caffeine and caffeine conditions.

H_o: $\mu R_{i, ii, iii}$ NC = $\mu R_{i, ii, iii}$ C

H_a: $\mu R_{i, ii, iii}$ NC ≠ $\mu R_{i, ii, iii}$ C

Where: NC = Non-caffeine conditions

C = Caffeine ingestion

R = Responses (Performance, Physiological and Oculomotor parameters)

i = Perceptual

ii = Cognitive

iii = Motor

Hypothesis 3: Perceptual, cognitive and sensory-motor performance are equal for both morning and evening conditions.

H_o: $\mu R_{i,\ ii,\ iii}\ M = \mu R_{i,\ ii,\ iii}\ E$

H_a: $\mu R_{i,\ ii,\ iii}\ M \neq \mu R_{i,\ ii,\ iii}\ E$

Where: M = Morning conditions

E = Evening conditions

R = Responses (Performance, Physiological and Oculomotor parameters)

i = Perceptual

ii = Cognitive

iii = Motor

Statistical analysis

The first stage of statistical analysis implemented a Shapiro-Wilks W test to establish whether the data obtained was normally distributed. Following this, descriptive statistics were performed in order to determine the means, standard deviations and coefficient of variation from the respective conditions. Group effects were conducted between each of the experimental groups as well as the control (alcohol vs. control, alcohol vs. caffeine and caffeine vs. control). These interactions were conducted by implementing a multi-variate analysis with group and gender as the categorical predictors. Morning vs. evening was the first within effect, simple vs. complex as the second and the effect of time as the third within effect. Statistical interactions and effects were assessed using a confidence interval of 95%; therefore a value of $p \leq 0.05$ was set.

CHAPTER IV

RESULTS

INTRODUCTION

The present investigation aimed to establish the performance, physiological and oculomotor related changes in human processing capabilities while affected by alcohol. Secondary aims included establishing the extent to which caffeine acts as an antagonising agent to ethanol and whether changes in performance could be related to daytime versus night time testing scenarios. To establish these effects, it was hypothesised firstly, that visual perception, cognitive and motor performance would be equal for both non-alcohol and alcohol conditions. Secondly, that all aspects of the human information processing chain would experience equal performance changes in non-caffeine+alcohol and caffeine+alcohol conditions. Lastly, that all performance changes for non-alcohol, alcohol, and *caffeine+alcohol* conditions would be equal in morning and evening testing scenarios.

Initial analysis ("Differentially-related effects") focused on differential experimentation and examines the difference between complex and simple conditions for each task. This analysis allows the principal researcher to establish if alcohol impairs a specific functional resource or if alcohol affects the information processing stream in its entirety. These analyses are conducted across all group comparisons (*alcohol* vs. *control, alcohol* vs. *caffeine+alcohol and caffeine+alcohol* vs. *control*) as a function of time, test batteries 1, 2 and 3 (TB1, TB2 and TB3).

Secondary analysis ("Task-related effects") demonstrates group- specific effects based on the average of simple and complex data, reflecting direct effects of the tasks on performance. Analysis includes interactions between the *alcohol* group and *control* group, to establish the effects of alcohol on human performance. A second analysis, *alcohol* vs. *caffeine+alcohol,* is run to establish the degree of caffeine antagonism on human performance in relation to alcohol intoxication. The last comparison, *caffeine+alcohol* vs. *control* groups looks to establish an alcohol-caffeine effect on performance. These effects, too, were analysed as a function of time, across TB1, TB2 and TB3.

Gender was analysed as a covariate in all analyses to establish whether or not sex has implications for performance- related changes due to the influence of alcohol, caffeine antagonism and time of day. Pre-processing of data included data normalisation of each dependent variable in relation to the baseline test. This was in an attempt to reduce the variability between the groups and to allow for a more accurate representation of data through relative group comparisons.

Owing to the volume of data, only statistically significant results will be discussed here. Furthermore, statistical effects tables will not be included in these results; rather, statistical values will be noted in the text. This is in order to reduce the number of tables and figures in this section. For an in-depth insight, tables of all effects are included in Appendix C.

BREATH ALCOHOL CONCENTRATION

Breath alcohol concentration was implemented as a control measure and was sampled five times per participant during each experimental session. As participants arrived at the laboratory the first measure was sampled. Thereafter, measures were sampled immediately prior to the onset of test battery 2 (TB2), post TB2, prior to TB3 and post TB3. The corresponding times for the above samples were 25 minutes post alcohol ingestion, a further 20 minutes later (45th minute), 25 minutes after sample 3 (70th minute) and a further 20 minutes post sample 4 (90th minute). Table X and Figure 14 represent the average breath alcohol concentration for each group at the above- mentioned times.

Table X: Time course of breath alcohol concentration [mg/L].

	0 Min	25 Min	45 Min	70 Min	90 Min
ALCOHOL	**PRE TEST**	**PRE TB2**	**POST TB2**	**PRE TB3**	**POST TB3**
Morning	(0.00 ± 0.00)	(0.058 ± 0.081)	(0.062 ± 0.054)	(0.056 ± 0.041)	(0.05 ± 0.030)
Evening	(0.00 ± 0.00)	(0.054 ± 0.015)	(0.053 ± 0.014)	(0.052 ± 0.026)	(0.040 ± 0.011)
CAFFEINE + ALCOHOL	**PRE TEST**	**PRE TB2**	**POST TB2**	**PRE TB3**	**POST TB3**
Morning	(0.00 ± 0.00)	(0.058 ± 0.020)	(0.059 ± 0.014)	(0.054 ± 0.008)	(0.048 ± 0.007)
Evening	(0.00 ± 0.00)	(0.048 ± 0.016)	(0.047 ± 0.010)	(0.044 ± 0.008)	(0.039 ± 0.008)

The *alcohol* group recorded higher breath alcohol concentrations throughout all sampled measures, however; these data elicited no significant effects between groups (F (1, 68) = 3.64, $p<0.06$).

Time of day at which alcohol is consumed shows a clear difference in the breath alcohol concentration sampled. The *alcohol* group consistently produced higher breath alcohol concentrations; the highest sample was detected during morning experimentation 45 minutes post ingestion (post TB2). Pre and Post TB2 sampling in morning experimentation induced the greatest variability within breath alcohol concentration, with a lesser variability demonstrated during evening experimentation. Pre and Post TB3 indicate a larger variability during evening experimentation when compared to the corresponding morning samples.

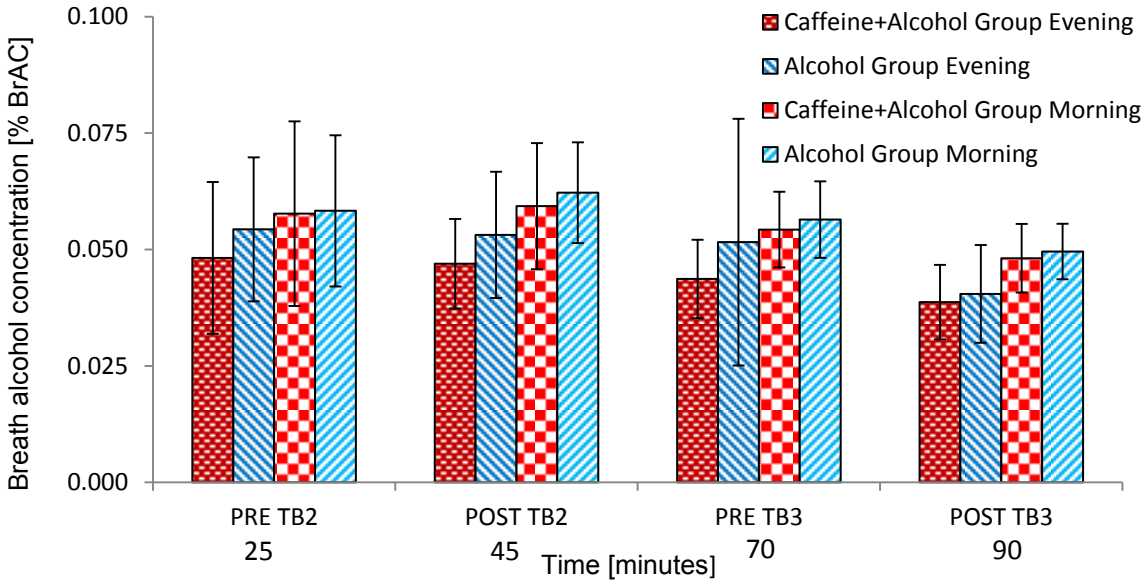

Figure 14: Time course of alcohol intoxication. Vertical bars denote standard deviation.

Peak alcohol concentration was reached approximately 30 - 45 minutes post alcohol ingestion, for evening and morning experimental sessions respectively. These data coincide with that of pre TB2 and post TB2 stages of testing. Based on these results, it would be expected that performance would be impaired to a greater extent during TB2. The highest breath alcohol concentration was sampled in the *alcohol* group post TB2 and produced an average reading of 0.311 mg/L. This result is notably different to the estimated breath alcohol

concentration of 0.075% (0.0375 mg/L) that was expected from the calculated Widmark equation.

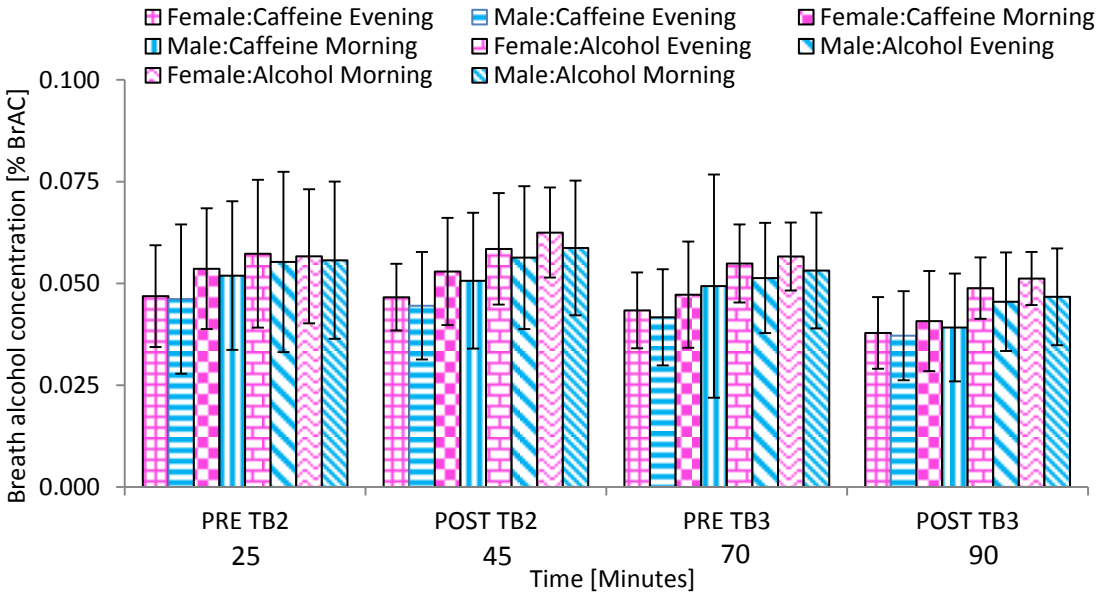

Figure 15: Breath alcohol concentration for males and females. Vertical bars denote standard deviation.

Gender comparisons revealed no significant differences as a function of group, time and as a function of time and time of day. As observed in Figure 15, female participants continually record higher breath alcohol concentrations as compared to male participants. The greatest amount of variability within the results is observed in male participants from the *caffeine+alcohol* group during evening experimentation. All *control* group participants were breathalysed upon arrival at the laboratory, with no participants testing positive for alcohol on the breath. Therefore testing continued as normal, under no influence of alcohol.

PERFORMANCE PARAMETERS

Participant performance measures were obtained from each task completed. Collectively, 14 performance variables were measured from the six dependent tasks, indicating alcohol-related performance effects. The structure of this section seeks to define the dependent performance variables by task, beginning with the visual perception tasks, delving into the

cognitive tasks and lastly focusing on the motor performance tasks. Each task will be discussed on a differential basis as well as an individual task basis.

Differential testing, as applied in this investigation, contends that any change in performance between simple and complex aspects of a task can be attributed to deterioration in one of the various resources associated with these stages of information processing.

Pre-processing of data involved the calculation of the complex-simple difference. Therefore, "differentially-related effects" that produce lower differences between groups indicate more consistent performance. Similarly, variables producing higher differences are indicative of larger variability in performance and hence depict deterioration in either simple or complex performance. Therefore, results will induce one of three outcomes; a positive difference, a negative difference and no difference in trends. A positive trend is indicative of complex performance achieving a higher response than simple task performance. A negative trend indicates the inverse, lower responses during complex performance. Lastly, a trend that is relatively constant and approximating zero reflects even performance between simple and complex tasks.

Visual Perception Performance

The accommodation, visual detection and reading tasks were utilised as the measures of visual perceptual performance. These tasks were utilised to tax the visual and perceptual stages during human information processing.

Accommodation Task

Two variables were selected for analysis with respect to the accommodation task. These variables, median reaction time and error rate, provided performance data across accommodation parameters.

Reaction Time

DIFFERENTIALLY-RELATED EFFECTS

Alcohol consumption produced an increased difference in reaction time for both the *alcohol* and *caffeine+alcohol* groups in comparison to the *control*. TB2 accrued the slowest reaction

for both experimental groups – this coinciding with the highest breath alcohol concentration sample from both experimental groups (Figure 16). The consumption of *caffeine+alcohol* demonstrated the slowest reaction times throughout all test batteries across all group comparisons. No significant differences were observed between experimental and *control* groups. A notable difference was however observed between the *caffeine+alcohol* and *control* group, (F (2, 204) = 2.98, p<0.06). The trends demonstrated by all groups were indicative of a greater reaction time recorded in complex accommodation.

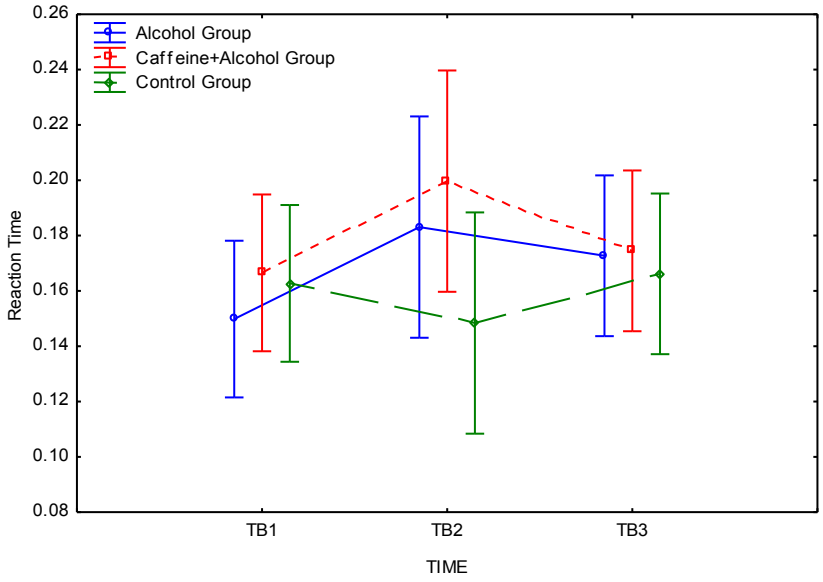

Figure 16: Relative effect of visual accommodation on reaction time. Vertical bars denote 95% confidence intervals.

A significant group effect was observed for time of day between *alcohol* and *caffeine+alcohol* as a function of complexity (F (1, 68) = 4.90, p<0.03). The *alcohol* group's reaction time was significantly faster in both morning and evening experimentation (Figure 17). The differences in reaction times between these groups were greater during evening experimental sessions. Alcohol consumption induced the slowest reaction times recorded in both experimental groups, as indicated during TB2.

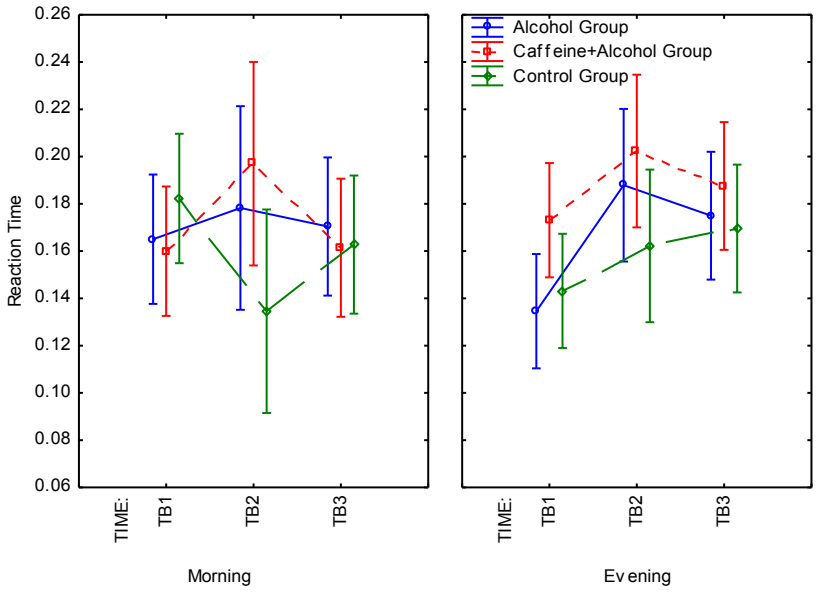

Figure 17: Relative effect of visual accommodation on reaction time for morning and evening experimentation (*alcohol vs. caffeine+alcohol* F (1, 68) = 4.90, p<0.03). Vertical bars denote 95% confidence intervals.

TASK-RELATED EFFECTS

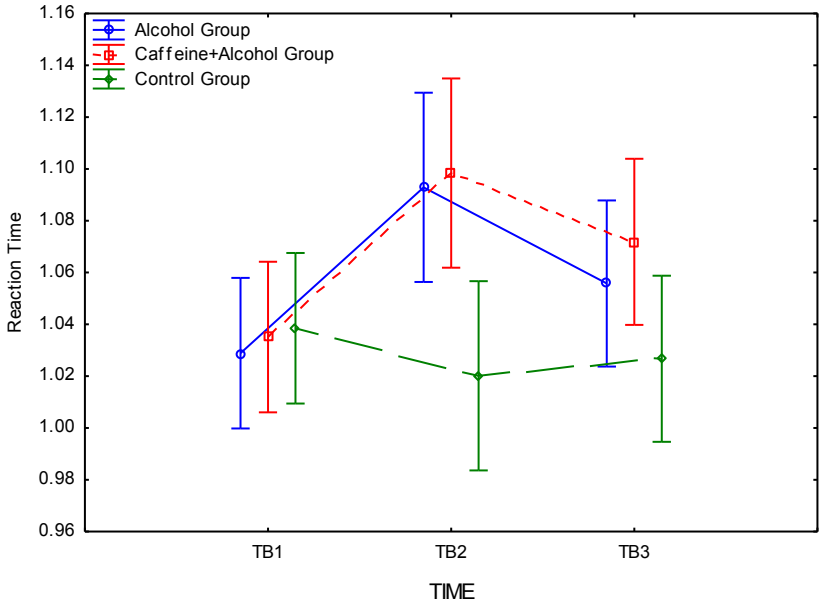

Figure 18: Relative reaction time during a choice reaction task (*alcohol* vs. *control*: F (2, 136) = 22.54, p<0.01) *caffeine+alcohol* vs. *control*: F (2, 136) = 18.91, p<0.01). Vertical bars denote 95% confidence intervals.

The *caffeine+alcohol* group reacted to the accommodating stimuli slower than any other group during TB2 and TB3. A significant task effect was present between both experimental groups and the *control* group. Reaction time was significantly slower for *alcohol* and *caffeine+alcohol* groups when compared to the *control* participants (F (2, 136) = 22.54, $p<0.01$) and (F (2, 136) = 18.91, $p<0.01$) respectively (Figure 18).

No significant findings for time of day effects within task-related effects were observed. Evening performance demonstrated higher reaction times, with *alcohol* and *caffeine+alcohol* participants responding marginally slower in TB2 and TB3, when compared to morning performance. Performance without the influence of alcohol was faster in the evening compared to morning test scenarios. Non-significant observations were quantified for gender. Reaction time for male and female participants was relatively similar across conditions. Alcohol consumption slowed reaction time in *alcohol* male participants during TB2 more than in *caffeine+alcohol*. The opposite result was however present during TB3.

Error rate: Wrong Critical Stimulus Responded

DIFFERENTIALLY-RELATED EFFECTS

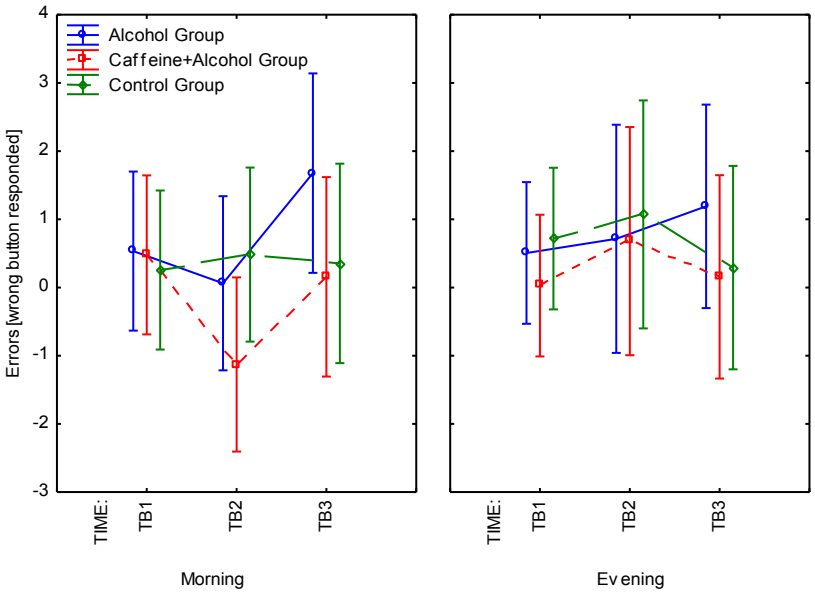

Figure 19: Relative effect of visual accommodation on error rate. Vertical bars denote 95% confidence intervals.

No significant differences in error rate were found between groups for simple vs. complex task performance, time of day effects or gender effects. The *alcohol* and *caffeine+alcohol* group comparison suggests that the aid of a stimulant leads to fewer errors. However, morning experimentation demonstrated a higher difference in errors for the *caffeine+alcohol* group. The *alcohol* group detected a lower number of errors in complex task performance in both morning and evening experimentation. The *caffeine+alcohol* group observed fewer errors during morning experimentation for simple task performance.

TASK-RELATED EFFECTS

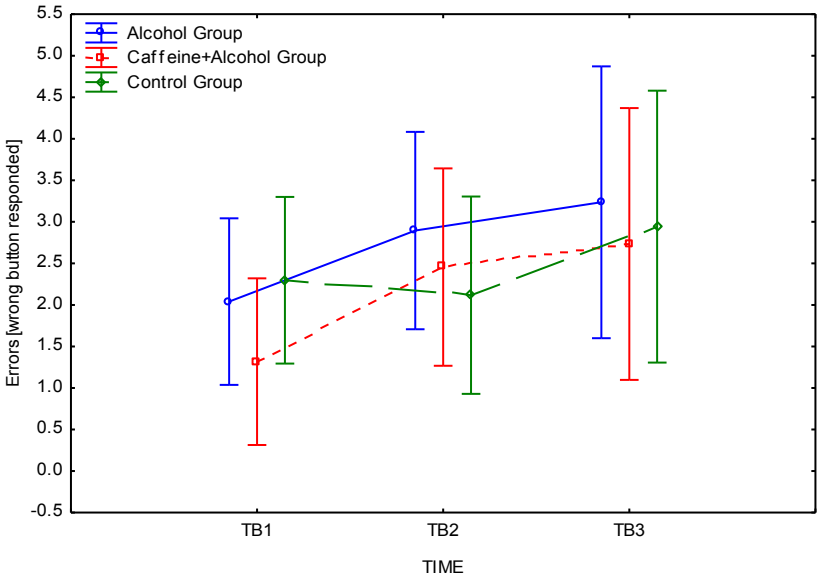

Figure 20: Relative error rate during a choice reaction task. Vertical bars denote 95% confidence intervals.

Error rate did not produce significant findings across all group comparisons; no time of day nor gender effects were present for error rate in the accommodation task. The *alcohol* group conceded most errors, followed by the *caffeine+ alcohol* and *control* groups (Figure 20).

Visual Detection

The visual detection task (see „experimental tasks", Chapter III) gives rise to a number of dependent variables, four of which were selected for analysis: median reaction time, error rate and reaction time vs. eccentricity correlation for both absolute and relative recordings.

Reaction Time

DIFFERENTIALLY-RELATED EFFECTS

Differential median reaction time was highest for the *caffeine+alcohol* group, these times were significantly higher than the control group"s (F (1, 68) = 8.65, p<0.01).

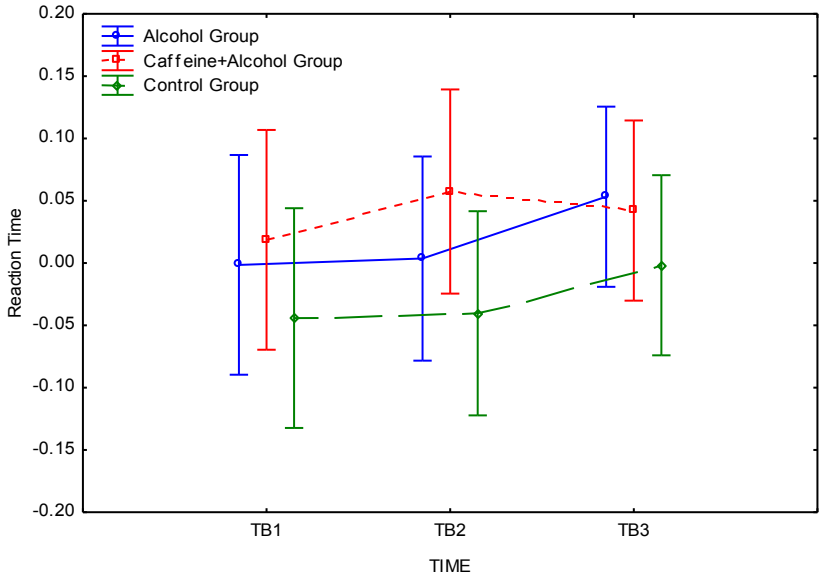

Figure 21: Relative effect of an increased information density during a visual detection task on reaction time (*caffeine+alcohol* vs. *control: F* (1, 68) = 8.65, p<0.01). Vertical bars denote 95% confidence intervals.

The *caffeine+alcohol* group"s trend indicated higher reaction times for complex task performance, with the control group achieving the opposite. The *control* group elicited a greater difference in performance between simple and complex tasks when compared to the *alcohol* group. The *alcohol* group recorded the most consistent reaction time between simple and complex trials. Reaction time demonstrated no significant effects between the *alcohol* and *caffeine+alcohol* groups nor in the comparison between the *alcohol* and. *control* groups. Alcohol consumption resulted in a decreased reaction time between simple and complex visual detection.

The *alcohol* and *caffeine+alcohol* group comparison demonstrated marked differences in reaction time for time of day (F (2, 136) = 2.76, p< 0.07).

TASK-RELATED EFFECTS

A significant main effect between *caffeine+alcohol* and *control* groups was observed throughout test batteries (F (2, 136) = 4.50, p<0.02), the *caffeine+alcohol* group showing a significantly higher reaction time. Further, alcohol ingestion increased reaction time in both experimental groups, thereafter (TB3) a reduction in reaction time was observed (Figure 22).

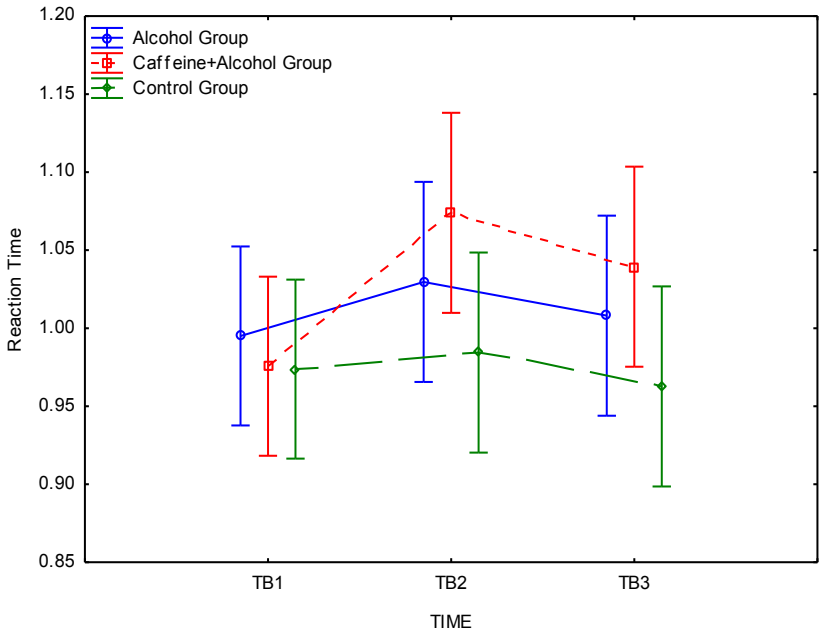

Figure 22: Relative reaction time during a visual detection reaction task (*caffeine+alcohol* vs. *control:* F (2, 136) = 4.50, p<0.02). Vertical bars denote 95% confidence intervals.

A significant gender effect was illustrated between the *alcohol* and *control* group for reaction time (F (2, 136) = 3.29, p<0.04). Therefore, the introduction of alcohol produced a significantly higher reaction time between genders for the visual detection task (Figure 23). The time function of the male *alcohol* participants compared to female participants from the same group was markedly different. It appears the effects of alcohol persist longer for female participants than for male participants, hence demonstrating elevated reaction times as observed in TB3.

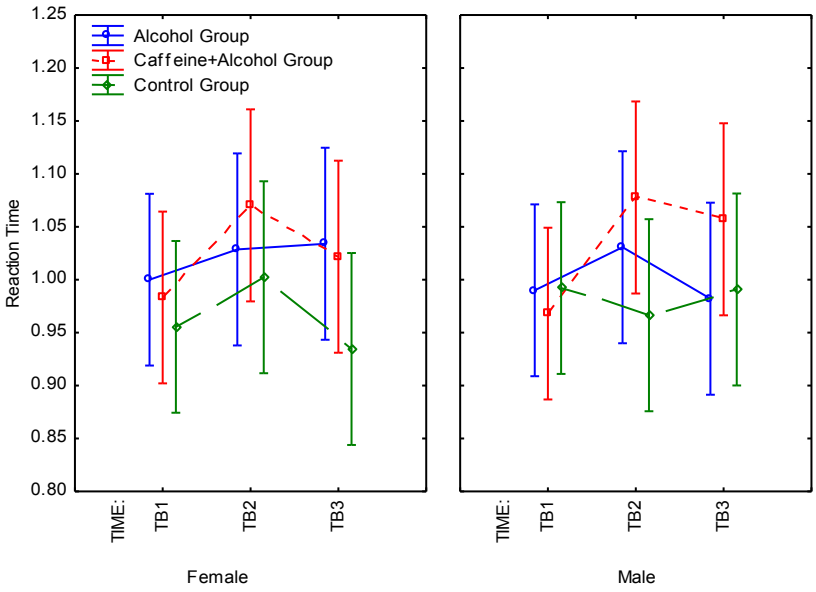

Figure 23: Relative reaction time during a visual detection reaction task for males and females (*alcohol* vs. *control:* F (2, 136) = 3.29, p<0.04). Vertical bars denote 95% confidence intervals.

Error rate: % of Stimuli Overlooked

DIFFERENTIALLY-RELATED EFFECTS

No significant effects between groups were observed for complexity- related error rates in the visual detection task. Significant time of day-related differences in the percentage of stimuli overlooked between simple and complex task performance were observed in the *alcohol* vs. *control* comparison (F (2, 136) = 3.71, p<0.03) and between the *alcohol* vs. *caffeine+alcohol* groups (F (2, 136) = 3.19, p<0.05: see Figure 24). The *alcohol* group when compared to the *control* and *caffeine+alcohol* groups elicited a greater difference in error rate between simple and complex task performance during the evening.

Evidently, alcohol consumption significantly increases complex task error rate during evening performance, with the largest number of stimuli being overlooked by the *alcohol* group during evening TB2. Unexpectedly, the *control* group participants demonstrated a higher difference in stimuli overlooked when compared to the *alcohol* and *caffeine+alcohol* groups during morning experimentation. The effect of alcohol for error rate was lower in morning experimentation when compared to evening experimentation.

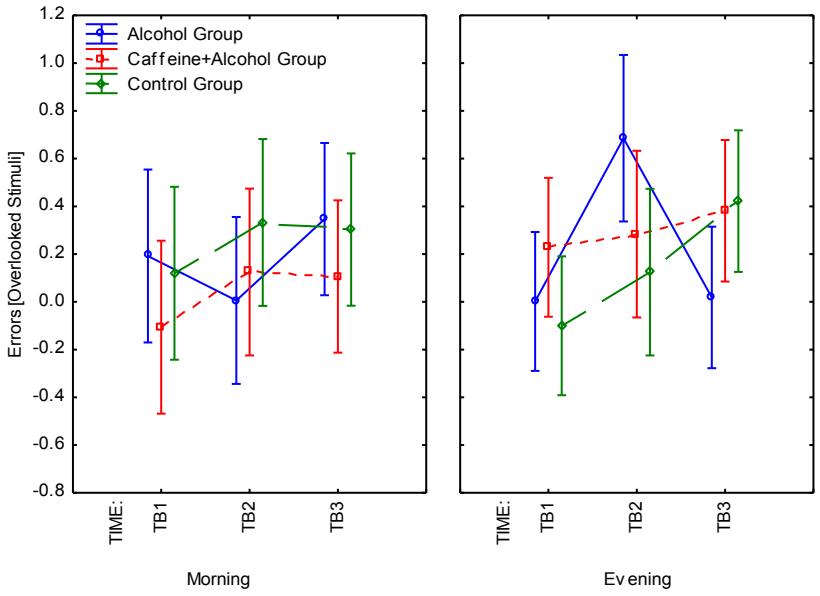

Figure 24: Relative effect of an increased information density during a visual detection task on error rate during morning and evening experimentation (*alcohol* vs. *control: F* (2, 136) = 3.71, p<0.03, *alcohol* vs. *caffeine+alcohol: F* (2, 136) = 3.19, p<0.05). Vertical bars denote 95% confidence intervals.

TASK-RELATED EFFECTS

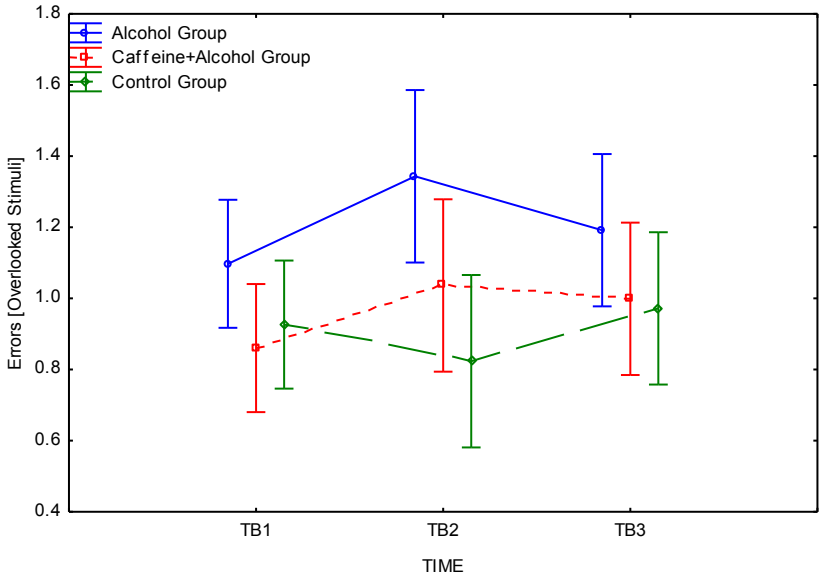

Figure 25: Relative error rate during a visual detection reaction task (*alcohol* vs. *control: F* (2, 136) = 5.77, p<0.01, *caffeine+alcohol* vs. *control: F* (2, 136) = 3.70 p<0.02). Vertical bars denote 95% confidence intervals.

Significant differences in error rate were observed between the *alcohol* and *control* group (F (2, 136) = 5.77, p<0.01) as well as in the *caffeine+alcohol* to *control* group comparison (F (2, 136) = 3.70 p<0.02). Alcohol consumption caused both experimental groups to overlook a significantly higher number of stimuli in comparison to the *control* group. As with the differentially-related performance, the highest error rates occurred immediately post alcohol ingestion (TB2; Figure 25).

A significant gender difference between the *alcohol* and *control* group for error rate was observed: Figure 26 (F (2, 136) = 3.36, p<0.04). Female participants from the *alcohol* group overlooked a significantly higher number of stimuli when compared to female participants from the *control* group. This result was similar for male participants from the respective groups. Furthermore, it was evident that error rate in both experimental groups, was higher for female participants than for male participants (Figure 26).

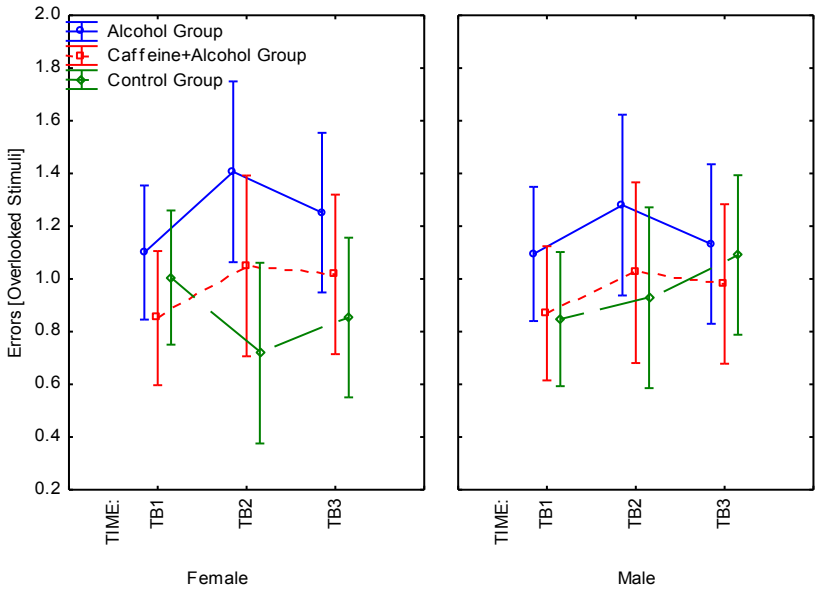

Figure 26: Relative error rate during a visual detection reaction task for males and females (*alcohol* vs. *control*: F (2, 136) = 3.36, p<0.04). Vertical bars denote 95% confidence intervals.

Reaction time vs. eccentricity correlation (Absolute)

This correlation represents a speed (reaction time) distance relationship. A positive correlation is representative of a slower reaction time for the peripheral stimuli and a faster reaction time to stars in the centralised vision. Conversely, a negative correlation is indicative of a slowed reaction time for centralised detection and faster detection of peripheral stimuli. A correlation approximating zero indicates equal reaction time for central and peripheral detection of stimuli.

DIFFERENTIALLY-RELATED EFFECTS

Statistical analysis indicates no significant effects between *alcohol* and *control* groups as well as between the *alcohol* and *caffeine+alcohol* groups for task complexity. Therefore, the increased complexity (addition of 40 stars) did not result in a significant change in performance between these groups over time. A significant difference was observed between *caffeine+alcohol* and *control* groups (F (1, 68) = 4.81, p<0.04).

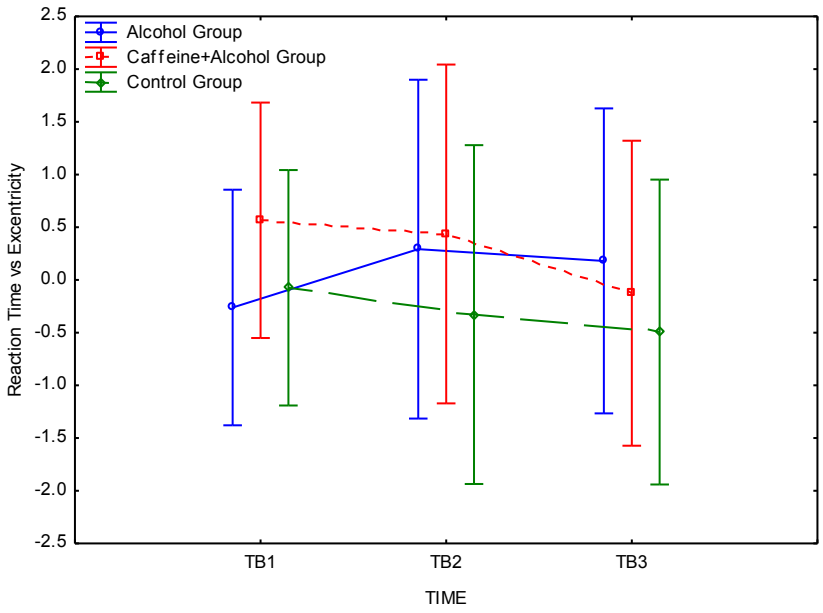

Figure 27: Relative effect of an increased information density during a visual detection task on reaction time eccentricity (*caffeine+alcohol* vs. *control:* F (1, 68) = 4.81, p<0.04). Vertical bars denote 95% confidence intervals.

A negative correlation for the *control* group was observed throughout the test batteries, indicating a faster reaction time for peripheral stimuli. The *alcohol* group, after the introduction of alcohol, demonstrated a negative correlation, altering to a positive correlation for TB2 and TB3 (Figure 27). This suggests that a more centralised "tunnel-like vision" is adopted under the influence of alcohol. Conversely, the *caffeine+alcohol* group adopted the opposite strategy, accruing faster reaction times for peripheral stimuli.

A significant gender effect for reaction time eccentricity was demonstrated between the *caffeine+alcohol* and *control* groups (F (1, 68) = 4.15, $p<0.05$). The *caffeine+alcohol* group showed a negative correlation, indicative of faster reaction time for peripheral stimuli. Male participants from all groups indicated a relatively even reaction time eccentricity between central and peripheral stimuli, as evidenced by the correlations approximating zero (Figure 28). On the other hand, female performance indicated a more variable reaction time eccentricity between groups, both experimental groups demonstrating a slower reaction time for peripheral stimuli post alcohol ingestion.

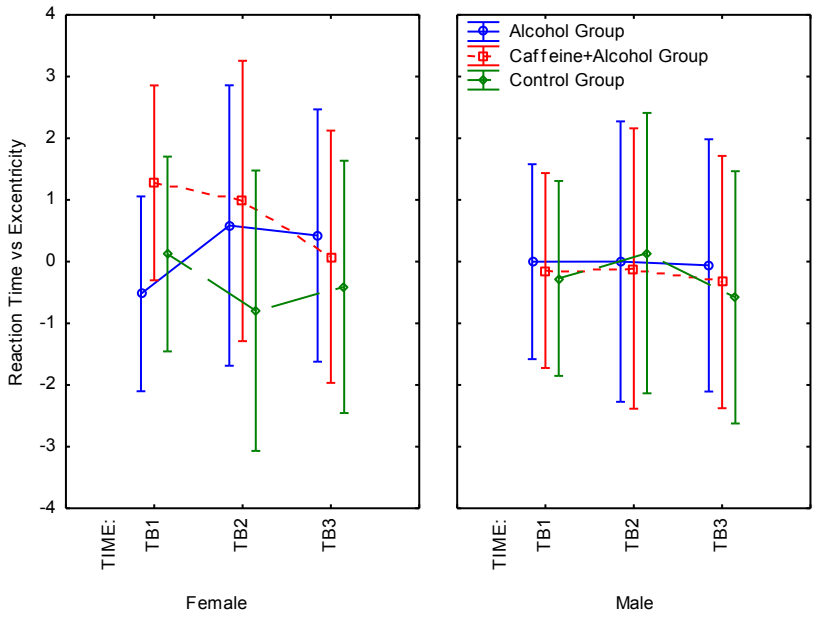

Figure 28: Relative effect of an increased information density during a visual detection task on reaction time eccentricity for males and females (*caffeine* vs. *control: F* (1, 68) = 4.15, $p<0.05$). Vertical bars denote 95% confidence intervals.

TASK-RELATED EFFECTS

No significant task- related effects were observed for absolute reaction time for eccentricity. This result was found across all groups, for time of day and gender differences as well as for interaction effects. Each group demonstrated positive correlations throughout all test batteries, indicating a slower detection speed for stimuli within the periphery and faster processing of centralised stars.

Reading Task

The reading task utilised for this investigation was designed to encompass both visual perception as well as cognitive processing. Visual perception would be based on the object recognition required to recognise each word, and cognitive processing to determine if each word had been misspelt or not. Performance output of this task included reading speed and error rate [number of spelling errors overlooked].

Reading Speed

DIFFERENTIALLY-RELATED EFFECTS

Alcohol consumption during complex and simple task performance disclosed no significant group differences, including time of day and gender effects. Furthermore, no significant interaction effects were demonstrated between time of day and gender. The most consistent reading speed between high and low resolution was observed in the *control* group, and the greatest variability observed within the *caffeine+alcohol* group. Alcohol ingestion increased reading speed in both experimental groups. Further, the negative trend indicated a slower reading speed in texts with low resolution.

TASK-RELATED EFFECTS

Alcohol consumption did not produce significant differences in reading speed across group comparisons for morning vs. evening experimentation, male vs. female performance nor for any interaction between these factors. Reading speed increased after the ingestion of alcohol in both experimental groups. The experimental groups demonstrated the fastest reading speeds while the *control* group demonstrated the slowest speed. Post alcohol ingestion, the *caffeine+alcohol* group demonstrated the fastest reading speed (TB2); thereafter, the *alcohol* group tended to read faster.

Error rate: spelling errors overlooked

DIFFERENTIALLY-RELATED EFFECTS

Error rate increased as a function of time for all groups; however no significant group differences were demonstrated by group or by gender. Alcohol consumption increased the propensity to overlook spelling errors in both high and low resolution reading; however, a higher number of errors were overlooked during low resolution reading. The highest difference in error rate between high and low resolution was obtained by the *caffeine+alcohol* group, closely followed by the *alcohol* group (Figure 29).

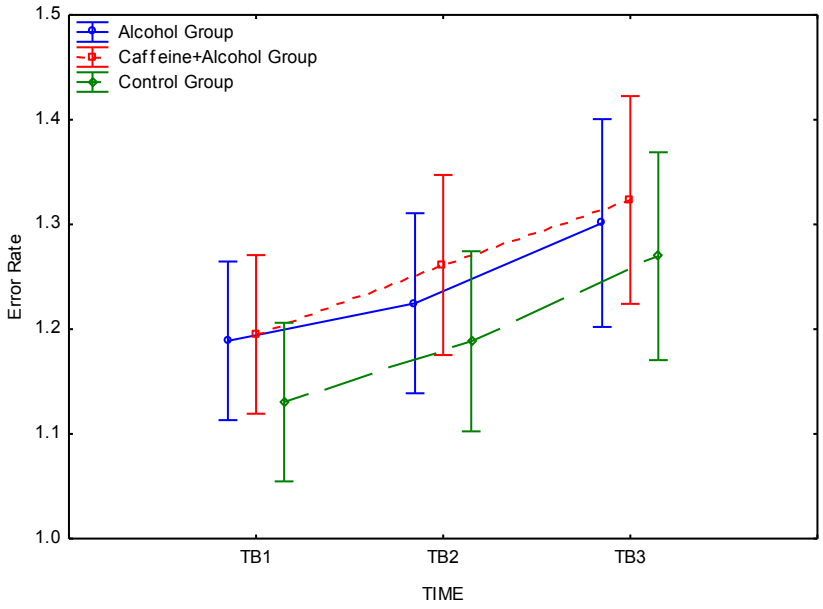

Figure 29: Relative effect of an increased visual pattern recognition difficulty on error rate. Vertical bars denote 95% confidence intervals.

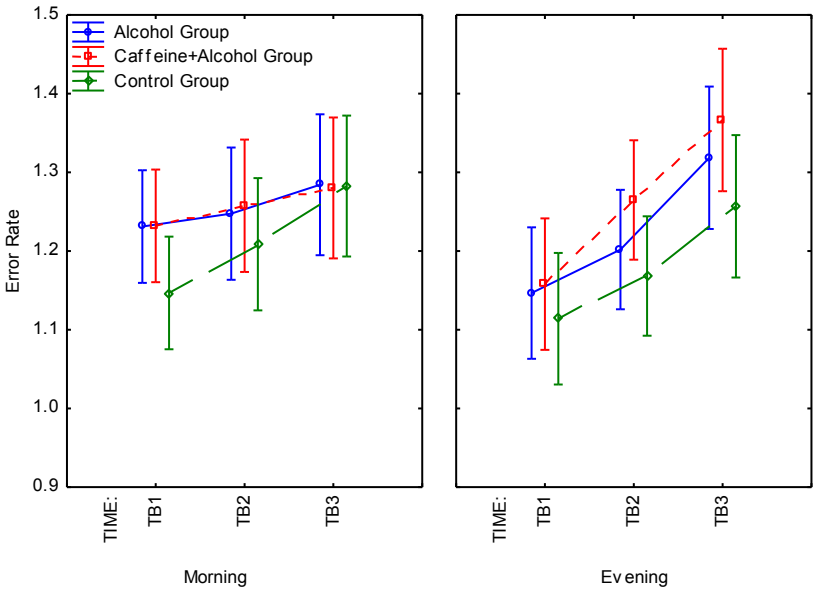

Figure 30: Relative effect of an increased visual pattern recognition difficulty on error rate during morning and evening experimentation (*alcohol* vs. *caffeine+alcohol:* F (1, 68) = 6.47, p<0.02). Vertical bars denote 95% confidence intervals.

A significant group effect for time of day-related error rate was detected between the *alcohol* and *caffeine+alcohol* group (F (1, 68) = 6.47, p<0.02). The *caffeine+alcohol* group incurred a significantly higher difference in the number of errors during evening experimentation. It appears that the impact of alcohol on error rate with a change in task complexity is greater during evening performance. This is based on the degree to which error rate increased during evening experimentation between TB2 and TB3 (Figure 30).

No significant gender-related effects were detected between groups for error rate. This suggests that the interaction of alcohol, complexity and gender does not significantly change cognitive processing ability and hence an individual‟s ability to identify spelling errors. A marked gender-related difference between *alcohol* and *caffeine+alcohol* was found for error rate (F (2, 136) = 2.98, p<0.06). No significant interaction effects were observed between alcohol comparisons.

TASK-RELATED EFFECTS

Significant differences in error rate were observed between the *alcohol* and *control* group as well as between the *alcohol* and the *caffeine+alcohol* group. Analysis indicates that the

alcohol group produced a significantly higher number of errors in both comparisons (*F* (2, 136) = 6.45, p< 0.01) and (*F* (2, 136) = 3.54, p<0.04) respectively.

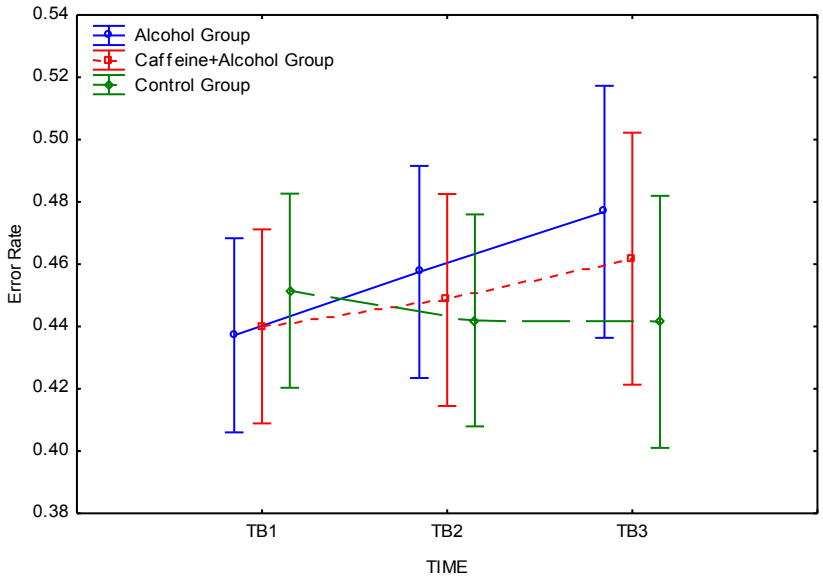

Figure 31: Relative error rate during a reading task (*alcohol* vs. *control:* (*F* (2, 136) = 6.45, p< 0.01, *alcohol* vs. *caffeine+alcohol:* (*F* (2, 136) = 3.54, p<0.04). Vertical bars denote 95% confidence intervals.

Memory Performance

Memory Recall (digit span) Task

This task produced performance parameters in the following forms: recall performance [correctly remembered numbers (%)] and response delay [seconds]. These performance parameters were produced for the following factors; simple vs. complex (5 vs. 7 numbers) short term vs. long term rehearsal (2 vs. 4 seconds rehearsal time) and an interaction between these factors. As with other performance parameters, morning vs. evening experimentation and gender differences were also analysed.

Recall performance [% Correct]

DIFFERENTIALLY-RELATED EFFECTS

Figure 32 illustrates group differences in performance for simple versus complex aspects of the memory recall task. The negative axis is indicative of complex recall recording a lower percentage of correct responses than simple recall.

A numerically large difference was observed between *alcohol* and *caffeine+alcohol* performance, however this difference did not yield significance. In this comparison, the *caffeine+alcohol* group shows more variable performance, demonstrating a larger difference between simple and complex aspects of recall performance. Alcohol consumption diminished recall ability for both experimental groups, as compared to TB1 and performance by the *control* group. Recall performance appeared to increase between TB2 and TB3- perhaps indicating an adaptation effect.

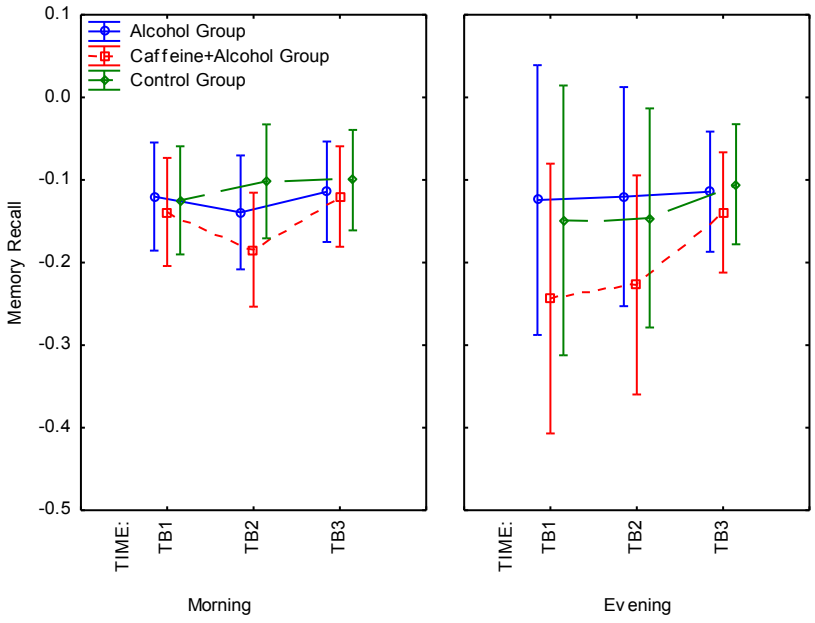

Figure 32: Relative effect of an increased memory capacity demand on memory recall (*caffeine+alcohol* vs. *control: F* (2, 136) = 3.43, p<0.04). Vertical bars denote 95% confidence intervals.

Recall performance was worse during evening experimentation across all group comparisons (Figure 40). A significant group effect for time of day is observed in the *caffeine+alcohol* and

control comparison. The difference in performance during evening experimentation was significantly greater in comparison to the difference throughout morning experimentation. This finding indicates a statistical power of (F = (2, 136), p<0.04). The lack of difference between *alcohol* and *control* performance is suggestive of time of day not having any effect on memory recall while under the influence of alcohol.

A significant gender related difference in recall performance was noticed between the *alcohol* and *control* group (F (1, 68) = 5.06, p< 0.03), p< 0.03). Female *alcohol* participants responded with the incorrect sequence chunking more often than the *control* females (Figure 33). Conversely, the difference in complexity-related recall performance from the male *alcohol* group participants was better than that from the *control* group. The difference in recall performance between five and seven numbers was lower for males from the *caffeine+alcohol* group and *control* group when comparison to the *alcohol* group is made. Within the *alcohol* group, male participants‟ recall percentage was higher than that of their female counterparts. No significant interaction effects between time of day and gender were observed between groups.

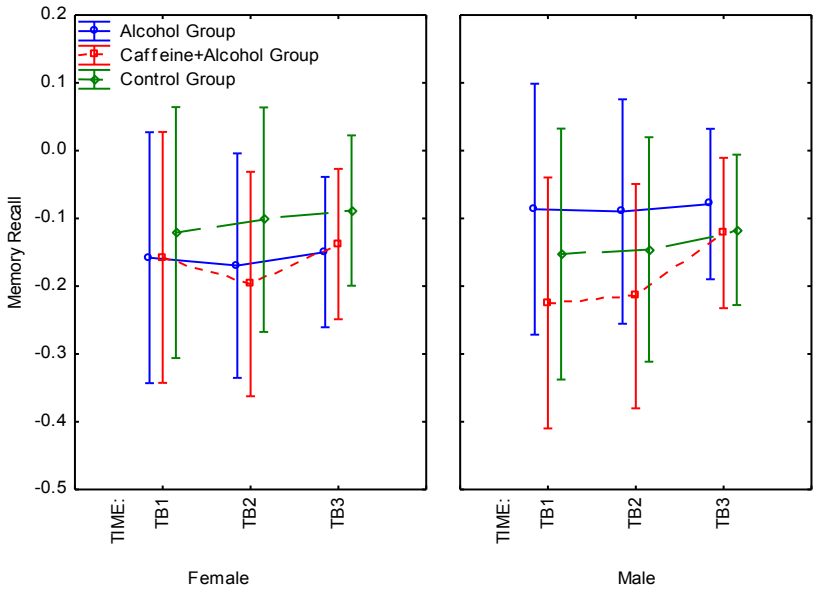

Figure 33: Relative effect of an increased memory capacity demand on memory recall for males and females (*alcohol* vs. *control: F* (1, 68) = 5.06, p< 0.03). Vertical bars denote 95% confidence intervals.

A comparison of short term vs. long term memory recall through differential analysis demonstrates no significant group effects (Figure 34). This result is observed for all combinations of group comparisons across morning vs. evening experimentation and gender-related effects.

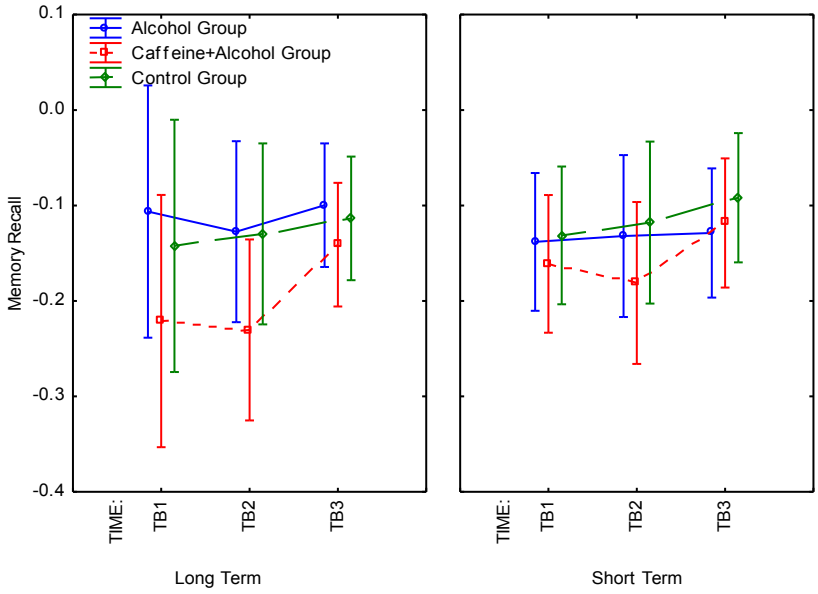

Figure 34: Relative effect of an increased memory rehearsal time on memory recall. Vertical bars denote 95% confidence intervals.

Long term rehearsal showed a higher percentage of correct responses by the *alcohol* and *control* groups. The *caffeine+alcohol* combination however, showed a smaller difference between simple and complex recall (i.e. a higher number of correct sequences) during the short term rehearsal period. Although the difference between simple and complex recall was lower during long term rehearsal, the *alcohol* and *caffeine+alcohol* group experienced deterioration in long term recall post alcohol ingestion – evidenced between TB1 and TB2. During short term rehearsal this effect was only present with the *caffeine+alcohol* group.

TASK-RELATED EFFECTS

A significant difference in recall was detected between the *caffeine+alcohol* and *control* groups (F (2, 136) = 3.11, p<0.05), wherein the *caffeine+alcohol* group incurred a greater number of incorrect responses (Figure 36). The effects of the consumption of alcohol on an individual‟s recall ability are exemplified by the decrease in correct responses between TB1 and TB2 in both experimental groups. Performance by the *alcohol* group when compared to the *caffeine+alcohol* group indicates that caffeine improves recall ability when consumed prior to alcohol. Further, the *alcohol* and *control* groups‟ average recall performance was markedly different (F = (2, 136), p< 0.08), with the *control* achieving a higher rate of accuracy in recall responses.

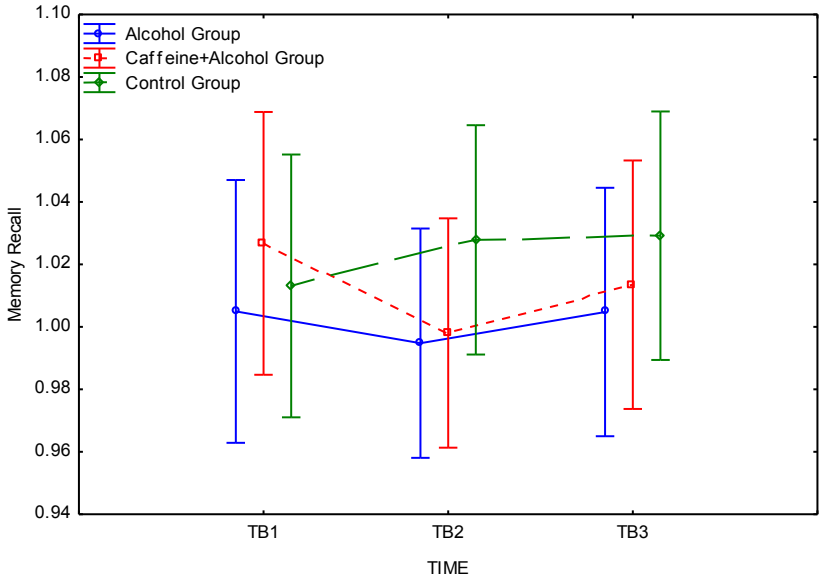

Figure 35: Relative memory recall during a memory recall task (*caffeine+alcohol* vs. *control: F* (2, 136) = 3.11, p<0.05). Vertical bars denote 95% confidence intervals.

Alcohol consumption in the morning, compared to the evening, results in significantly reduced memory recall ability (Figure 36). This was observed in the comparison between the *alcohol* and *control* groups (F (2, 136) = 3.74, p< 0.03). Caffeine consumption prior to alcohol consumption, in the morning, did not seem to improve memory recall. Therefore, it appears that memory recall is more sensitive to the time of day in which the memory task is

performed. As observed by evening experimentation, recall performance appeared to be more consistent, and tended to increase from TB2 to TB3.

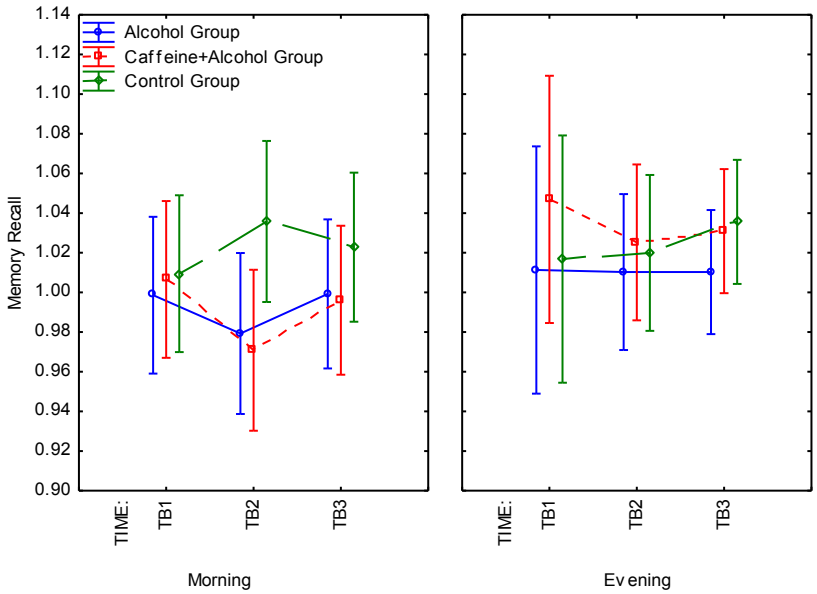

Figure 36: Relative memory recall during a memory recall task for morning and evening experimentation (*Alcohol* vs. *control: F* (2, 136) = 3.74, p< 0.03). Vertical bars denote 95% confidence intervals.

Statistical analysis does not yield any significant differences in memory recall for gender-related performance. Further, no interaction effects are presented as a factor of morning vs. evening and gender. Similarly, short vs. long term rehearsal produced no significant effects through any group combination, inclusive of time of day, gender and the interaction between the two.

Response Delay

Response delay represents the time taken from the end of the rehearsal period to the beginning of the participant"s response, indicating the participant"s level of arousal.

DIFFERENTIALLY-RELATED EFFECTS

Analysis between simple and complex response delay reveals a significant difference between the *caffeine+alcohol* and *control* groups, with the *caffeine+alcohol* group demonstrating a significantly higher delay (*F* (1, 68) = 9.32, p< 0.01: see Figure 37). Alcohol

consumption increases the difference in response delay between complex and simple memory recall when compared to the *control* group (Figure 28). The positive trends witnessed in all groups are indicative of complex recall incurring a slower response delay. The number of digits in the task therefore affects the corresponding response delay.

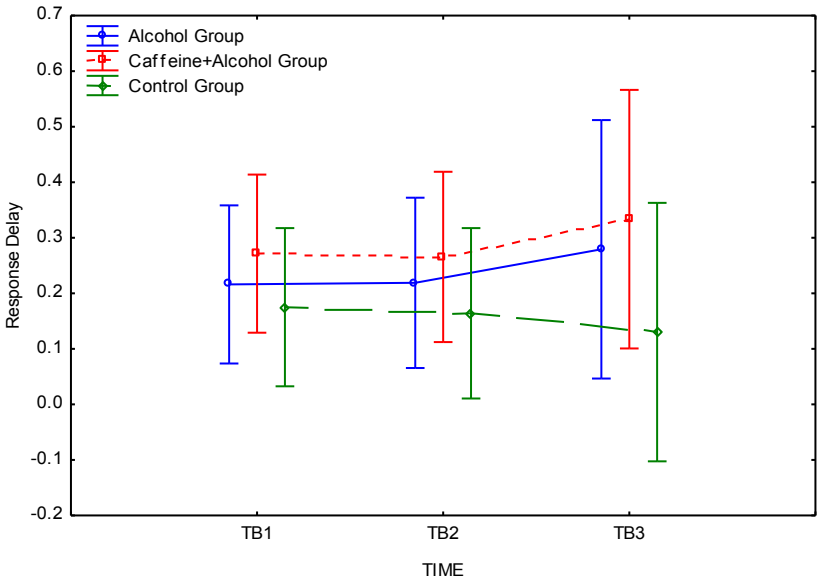

Figure 37: Relative effect of an increased visual pattern recognition difficulty on response delay (*caffeine+alcohol* vs. *control: F* (1, 68) = 9.32, p< 0.01). Vertical bars denote 95% confidence intervals.

Figure 38 indicates that the time of day at which the memory task was conducted significantly affected response delay of the *caffeine+alcohol* groups when compared to that of the *control* group (*F* (1, 68) = 4.90, p< 0.05). Comparison between the *alcohol* and *caffeine+alcohol* groups indicates that the consumption of caffeine prior to alcohol did not improve the difference in response delay between simple and complex memory recall. Pure alcohol consumption did not significantly impair response delay when compared to the control group. The comparison between *alcohol* and *control* groups during morning examination shows similar response delay during TB2, perhaps reducing the chance of observing a significant effect between these groups.

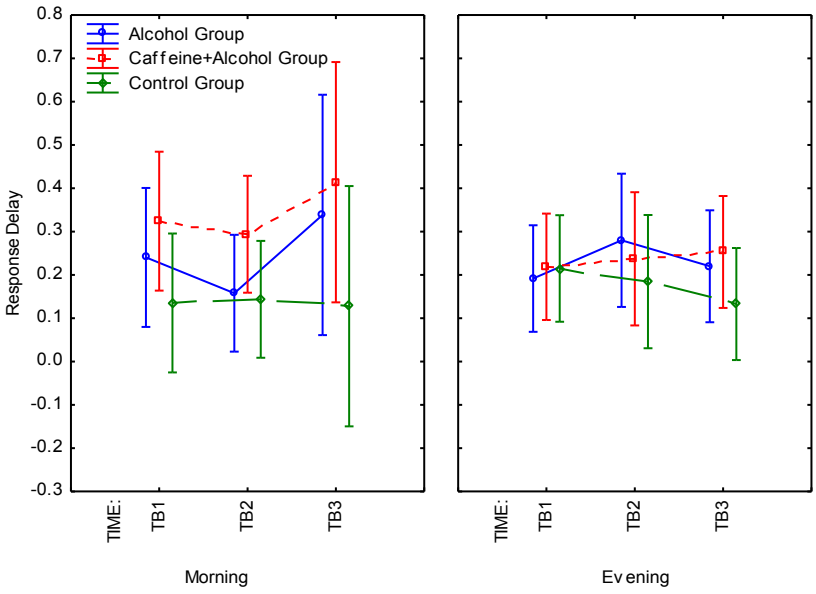

Figure 38: Relative effect of an increased visual pattern recognition difficulty on response delay for morning and evening experimentation (*caffeine+alcohol* vs. *control: F* (1, 68) = 4.90, p< 0.05). Vertical bars denote 95% confidence intervals.

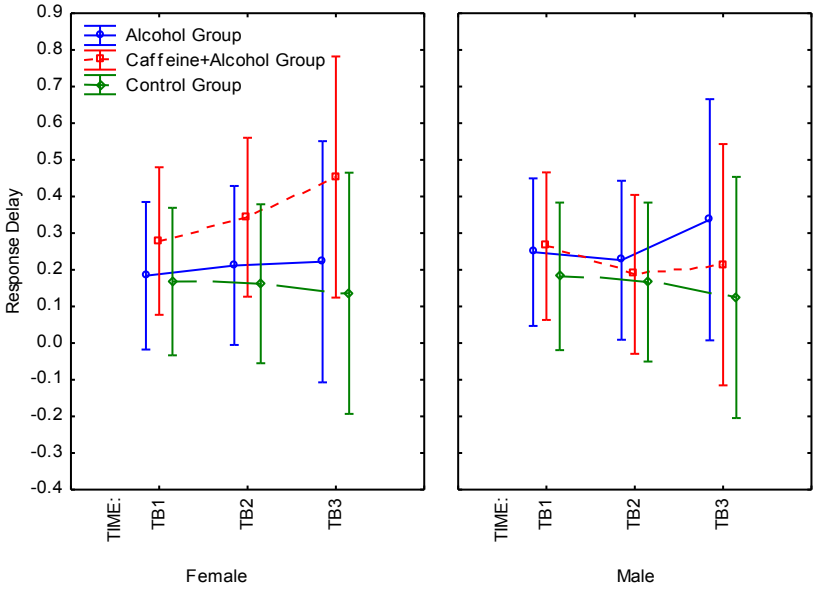

Figure 39 Relative effect of an increased visual pattern recognition difficulty on response delay for males and females (*Alcohol* vs. *caffeine+alcohol*: *F* (1, 68) = 4.34, p<0.05). Vertical bars denote 95% confidence intervals.

A significant gender effect within the *alcohol* and *caffeine+alcohol* group comparison is demonstrated (F (1, 68) = 4.34, p<0.05). The females in the *caffeine+alcohol* group recorded significantly larger difference in response delay between simple vs. complex memory recall, when compared to the same sex in the *alcohol* group (Figure 39). Male performance from these same groups was relatively comparable.

Rehearsal time between the *caffeine+alcohol* and *control* groups indicates a substantially higher response delay elicited by the *caffeine+alcohol* (F (1, 68) = 3.08, p< 0.05). Figure 40 indicates that short term rehearsal resulted in a greater difference in response delay between simple and complex memory recall in all groups examined. Furthermore, the response delay trends indicate greater variability during short term rehearsal between the groups. No significant differences as an effect of pure alcohol were observed for differences between simple and complex memory recall for short and long term rehearsal, when compared to the *control* group.

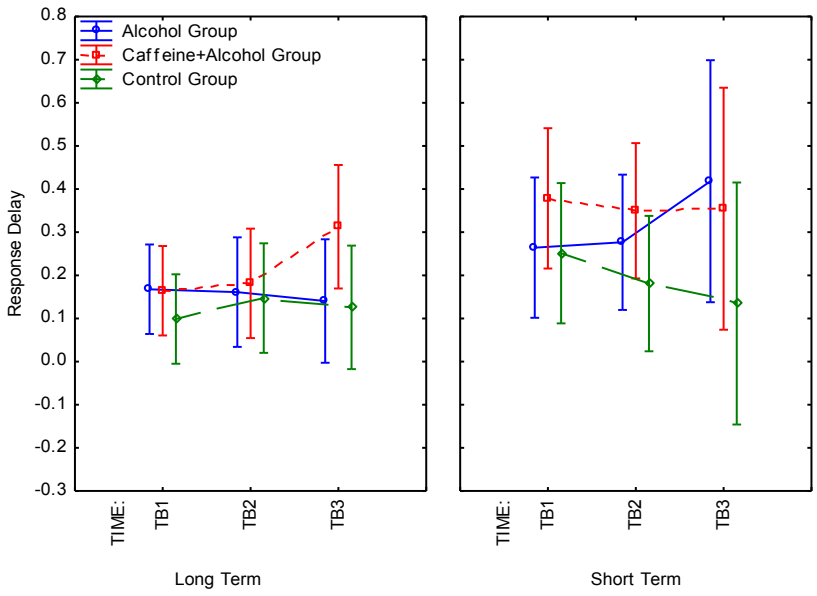

Figure 40: Relative effect of an increased memory rehearsal time on response delay (*caffeine+alcohol* vs. *control*: F (1, 68) = 3.08, p< 0.05). Vertical bars denote 95% confidence intervals.

Significant interaction effects of gender, complexity and rehearsal period are demonstrated in the *alcohol* and *caffeine+alcohol* comparison (F (1, 68) = 3.84, p< 0.03) and between the *alcohol* and *control* groups (F (1, 68) = 2.99, p< 0.06).

TASK-RELATED EFFECTS

Response delay produced no significant effects across all group comparisons for the memory task. Further, no significant time of day effects are demonstrated between group comparisons. A significant gender-related difference for response delay emerges in the *alcohol* vs. *control* comparison (F (2, 136) = 3.34, p< 0.04). Figure 41, illustrates that alcohol consumption improved female *alcohol* participants‟ response delay when compared to the same sex from the *control* group. Conversely, male participants in the alcohol group tended to respond slower than the *control* participants of the same sex, post- alcohol consumption.

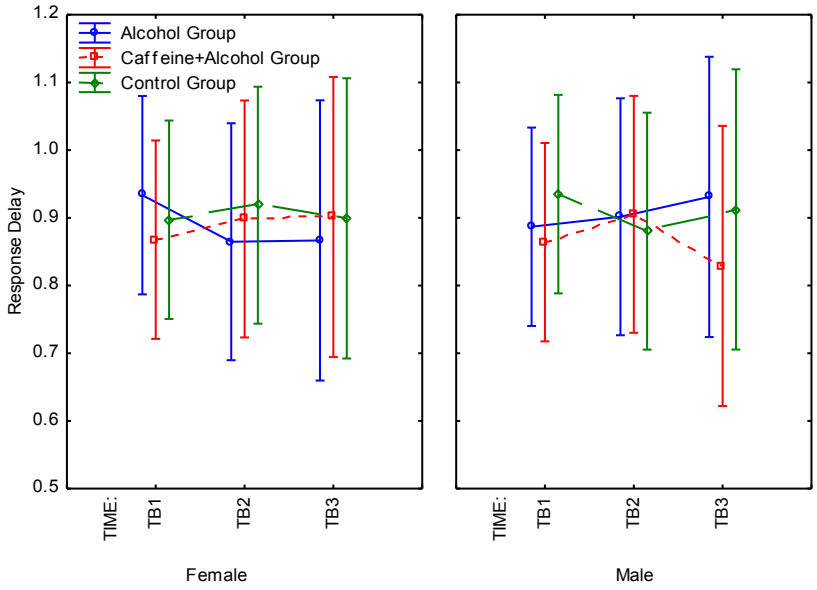

Figure 41: Relative response delay during a memory recall task for males and females (*alcohol* vs. *control: F* (2, 136) = 3.34, p< 0.04). Vertical bars denote 95% confidence intervals.

Response delay during long term and short term rehearsal demonstrates no significant group effects. This included time of day, gender and the interaction of these two effects. As with the differentially-related effects, short term rehearsal resulted in higher response delays than long term rehearsal.

Motor Performance

Motor output is the last stage of the information processing sequence. Motor performance was evaluated in two tasks, a stimulus response task (modified Fitts task) and a neural reflex task.

Stimulus Response Task

This modified Fitts task measured the following parameters: response time and target deviation. The design of this task in combination with differential analysis allowed for motor programming and motor programming precision to be determined (See „experimental tasks", Chapter III). For differentially-related effects the difference in response time indicates group differences in motor programming. Furthermore, with reference to task-related effects this variable represents simple stimulus-response time indicating the participants" level of arousal. The differential aspect of target size measures a behavioural parameter of motor precision. Although target size was not enforced as a dependent variable, but rather as a behavioural parameter, if the participant aims for a reduced target deviation, the 12 mm stimulus requires greater precision than that of the 24 mm stimulus. This section will therefore be interpreted with reference to both motor programming and response time and an interaction between these and target size.

Response Time

DIFFERENTIALLY-RELATED EFFECTS

No significant effects for motor programming were observed between simple and complex tasks across group comparisons, inclusive of time of day effects, gender effects and the interaction between the two. Alcohol consumption increased the participants" ability to predict movement direction and hence motor programming time. This is also observed for the *control* group; however this group showed the fastest motor programming ability of the three groups tested. With reference to the two experimental groups, immediately post alcohol ingestion, the *alcohol* group had a faster motor programming ability when compared to the *caffeine+alcohol* group (TB2). Although the difference between the experimental groups and *control* group is non-significant, the decrement in performance post alcohol ingestion is clearly shown.

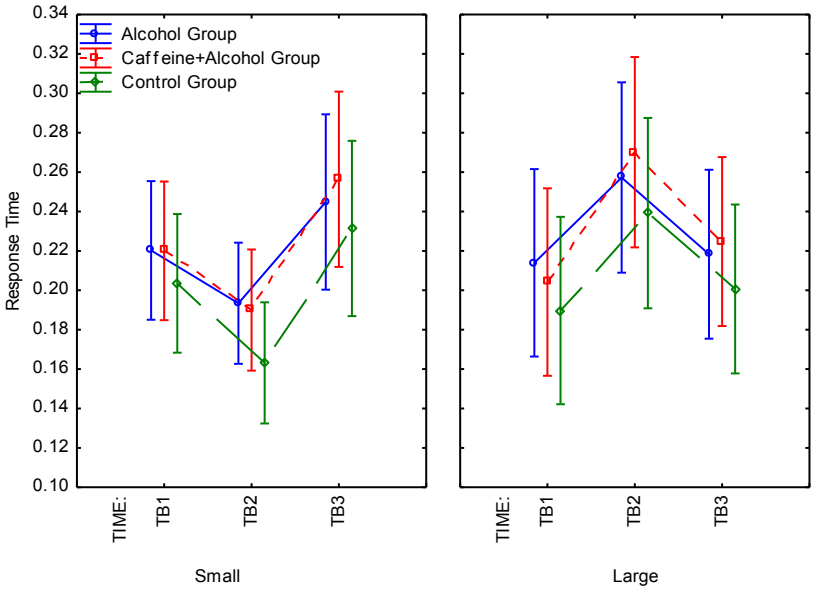

Figure 42: Relative effect of an increased motor programming difficulty on response time. Vertical bars denote 95% confidence intervals.

The interaction between motor programming and size of the stimulus indicates motor programming is affected by target size (Figure 42).Motor programming functions over time demonstrate an inverse relationship to target size. A general trend among groups was an increased motor programming time for the smaller target size, while the larger size target evoked faster motor programming. Alcohol ingestion (TB2) produced a slower motor programming response for both sized stimuli. Although this result does not bear significance, a substantial difference is observed between the *alcohol* and *control* groups for motor programming as a function of stimulus size (F (2, 136) = 3.80 $p<0.06$). Therefore, the effect of stimulus size in combination with alcohol consumption shows profound effects on an individual"s ability to organise and program motor responses.

TASK-RELATED EFFECTS

Task-related effects yield no significance in all combinations for factors of morning vs. evening, gender-related differences or for any interaction between these factors.

Target Deviation

DIFFERENTIALLY-RELATED EFFECTS

No significant effects for target deviation are observed across group comparisons, inclusive of time of day effects, gender effects and the interaction between the two.

The greatest difference in target deviation between anywhere (non-predictable) and central (predictable) movement direction was displayed by the *alcohol* group. Alcohol consumption initially improved the *alcohol* group"s ability to predict movement direction; thereafter, this improvement diminished. The consumption of caffeine prior to alcohol initially increases the difference in predictable and non-predictable movement direction and hence decreases the precision when reacting to the stimuli. The *control* group showed a steady increase in target deviation between predictable and non-predictable moment direction, favouring non-predictable movement direction.

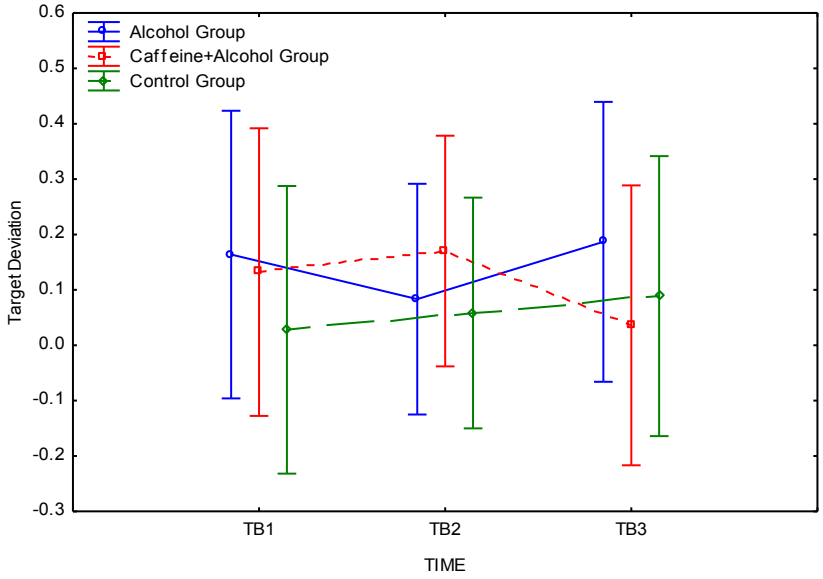

Figure 43: Relative effect of an increased motor programming difficulty on target deviation. Vertical bars denote 95% confidence intervals.

Alcohol consumption failed to reveal any significant effects in target deviation as a function of size between predictable and non-predictable movement directions. Comparisons between the *alcohol* and *control* groups as well as between the *alcohol* vs. *caffeine+alcohol* groups do not elicit significant group effects, time of day effects nor gender effects. Comparison between

the *caffeine+alcohol* and the *control* groups indicates a significant time of day effect (F (1, 68) = 12.28, p<0.01). In this instance, the *caffeine+alcohol* group incurs higher differences in target deviation between predictable and non-predictable movement directions.

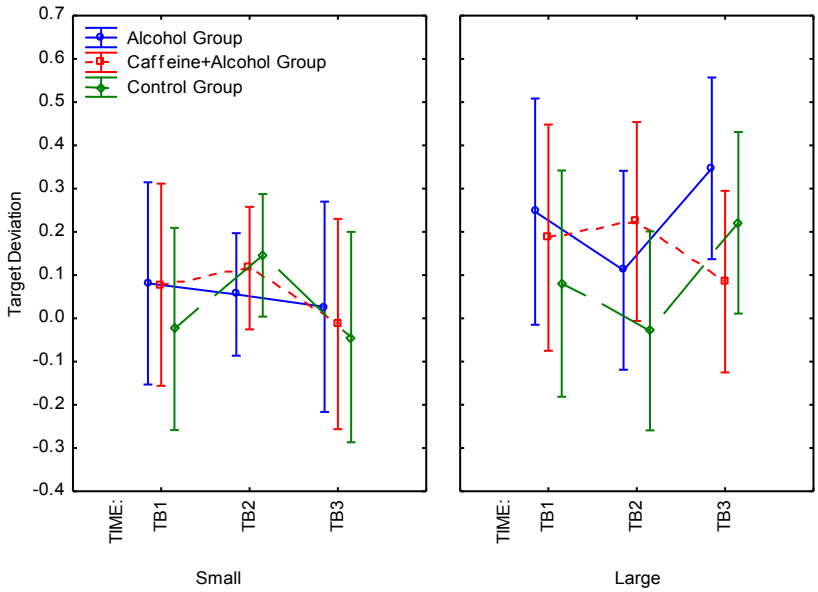

Figure 44: Relative effect of an increased motor programming difficulty on target deviation. Vertical bars denote 95% confidence intervals.

As seen for response time, target deviation bears an inverse relationship to target size. Generally, all groups demonstrated a larger target deviation for non-predictable movement directions for a small stimulus and a smaller target deviation for the same movement direction for large stimuli. The largest difference in predictable and non-predictable movement direction for target deviation was displayed by the *alcohol* group for the large stimulus.

TASK-RELATED EFFECTS

Target deviation demonstrates two significant main effects. A significant difference is observed between results for the *alcohol* and *control* groups (F (2, 136) = 5.88, p< 0.01), the *alcohol* group incurring a significantly larger target deviation than the *control* group (Figure 45). Alcohol consumption initially improved target deviation (TB2) however, thereafter, target deviation increased and performance deteriorated.

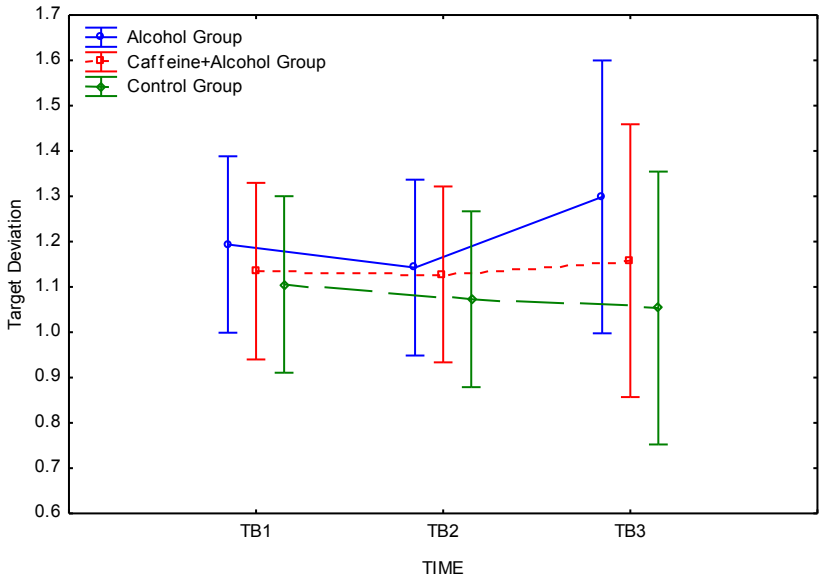

Figure 45: Relative target deviation during a Fitt‟s task (*alcohol* vs. *control: F* (2, 136) = 5.88, p< 0.01, *caffeine+alcohol* vs. *control: F* (2, 136) = 6.65, p<0.01). Vertical bars denote 95% confidence intervals.

The second main effect, observed between results for the *caffeine+alcohol* and *control* groups, demonstrates a significantly higher target deviation and hence lower precision within the *caffeine+alcohol* group (*F* (2, 136) = 6.65, p<0.01). The trend between these groups is similar to that witnessed between the *alcohol* and *control* groups; however, the extent of the increase witnessed in the *alcohol* group was not as large in the *caffeine+alcohol* group.

Target size significantly influenced target deviation and hence precision of motor programming performance. Alcohol consumption in the *alcohol* group resulted in a significant decrement in precision performance when compared to the *control* group (*F* (2, 136) = 9.96, p<0.01). Alcohol impairment caused participants to react less accurately for large stimuli and more accurately for small stimuli, when compared to the control group (Figure 46).

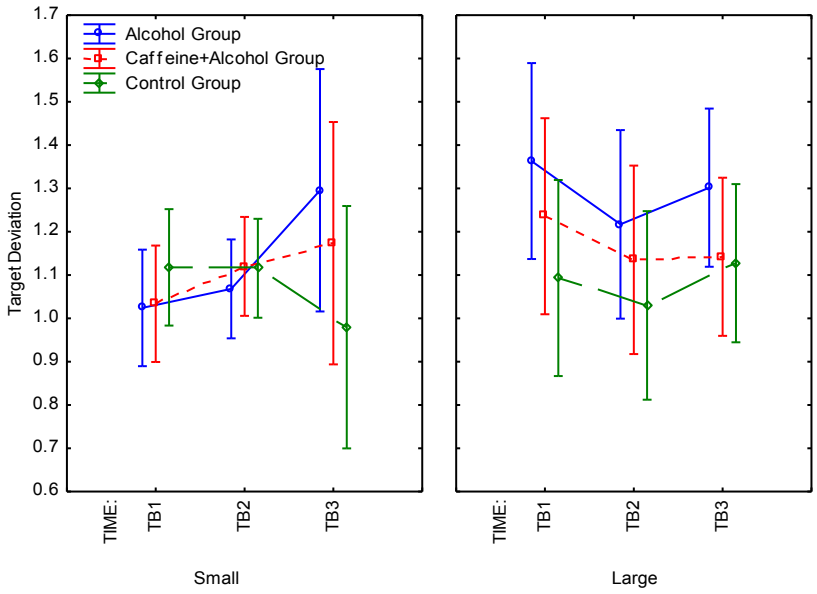

Figure 46: Relative target deviation during a Fitt‟s task (*alcohol* vs. *control: F* (2, 136) = 9.96, p<0.01). Vertical bars denote 95% confidence intervals.

Neural Reflex Task

Neural reflexes are closed- loop feedback systems, which require afferent and efferent information to produce the required responses. For this investigation neural reflexes were measured in a simplistic driving simulator via the constant feedback provided by information capacity and steering alteration.

Information Capacity

Information Capacity is the Log^2 of the reciprocal value of the reaction delay; this therefore represents the reaction delay elicited by participants when performing line tracking in a driving simulator task. This measure is an expression of information processing capacity and is measured in [bit/s].

DIFFERENTIALLY-RELATED EFFECTS

A significant difference between steering complexity is observed between the *caffeine+alcohol* and control groups (*F* (1, 68) = 4.08, p<0.03) (Figure 47).

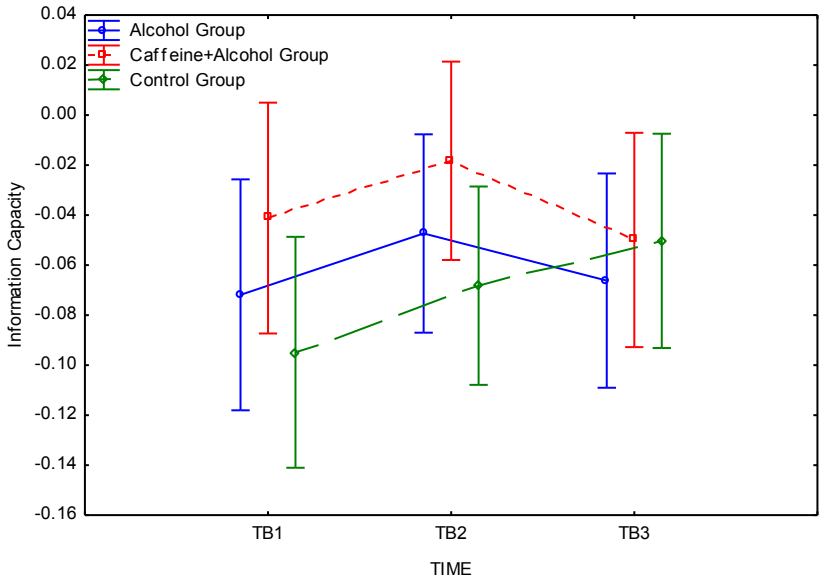

Figure 47: Relative effect of an increased proprioceptive feedback demand on information capacity (*caffeine+alcohol* vs. *control* (F (1, 68) = 4.08, $p<0.03$). Vertical bars denote 95% confidence intervals.

This effect indicates that caffeine consumption prior to alcohol consumption decreased the difference in deviation (as measured by information capacity) between high and low sensitivity steering when compared to the *control* group's information capacity. This suggests that the combination of caffeine and alcohol significantly improves proprioceptive control at the breath alcohol concentrations tested. Furthermore, the consumption of alcohol also produced a reduced difference between high and low sensitivity information capacity when compared to the *control* group. The performance function for the two experimental groups is similar throughout testing, with the lowest difference in information capacity elicited post alcohol consumption.

The difference in performance during morning and evening experimentation between the *caffeine+alcohol* and *control* groups was significant (F (1, 68) = 8.00, $p<0.01$). This difference becomes apparent when evening experimentation is examined. Moreover, the variability in information capacity between high and low steering sensitivity was far greater in the *control* group. Clearly, alcohol consumption during the evening for both experimental groups improved the difference in information capacity between high and low sensitivity.

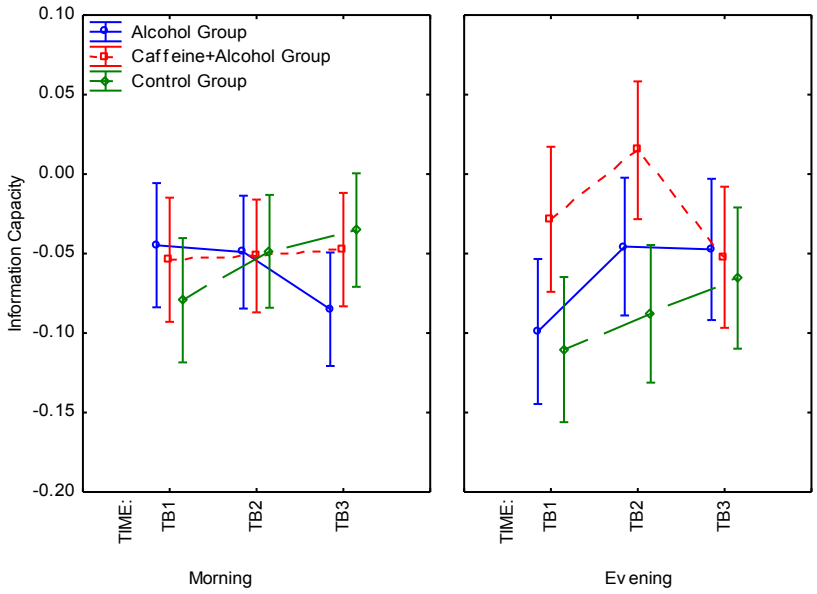

Figure 48: Relative effect of an increased proprioceptive feedback demand on information capacity for morning and evening experimentation (*caffeine+alcohol* vs. *control: F* (1, 68) = 8.00, p<0.01). Vertical bars denote 95% confidence intervals.

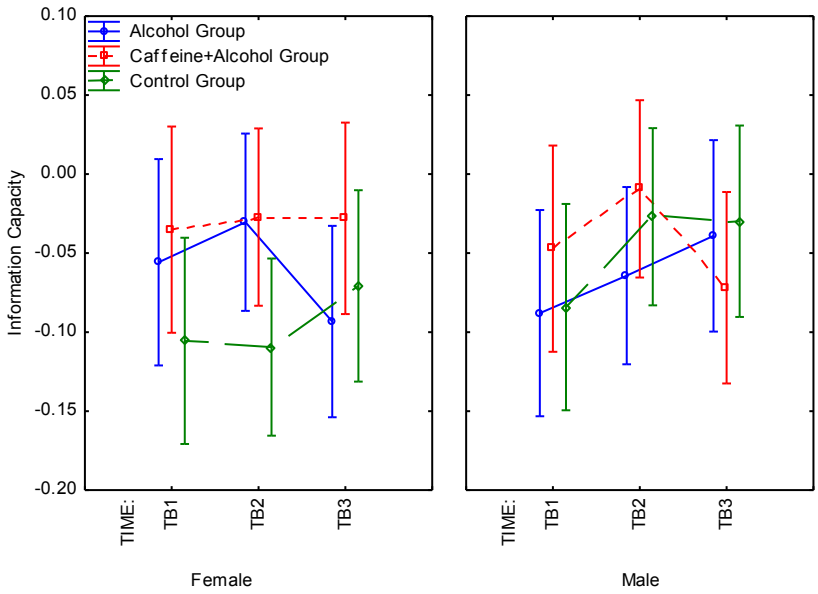

Figure 49: Relative effect of an increased proprioceptive feedback demand on information capacity for males and females (*alcohol* vs. *caffeine+alcohol:* (*F* (2, 136) = 2.39, p<0.03, *caffeine+alcohol* vs. *control* (*F* (2, 136) = 4.08 p<0.05). Vertical bars denote 95% confidence intervals.

Gender driving-related performance when under the influence of alcohol (see Figure 49) illustrated large variability in reaction delay between male and female participants between groups. The *caffeine+alcohol* group‟s performance between high and low sensitivity was significantly better when compared to both the *control* (F (2, 136) = 4.08 $p<0.05$) and *alcohol* groups (F (2, 136) = 2.39, $p<0.03$). Male participants‟ information capacity improved to a larger extent between TB1 and TB2, when compared to female differences. However, female participants from the experimental groups demonstrated a consistently smaller difference in complexity-related information capacity. This suggests that alcohol consumption affects females‟ proprioceptive control to a lesser extent; but improves males‟ proprioceptive control at the same level of alcohol consumption.

TASK-RELATED EFFECTS

No significant differences in information capacity were observed between groups, inclusive of time of day, gender effects as well as any interaction of these variables.

Steering Alteration Frequency

This performance variable considers the alteration frequency of vehicle control by measuring oscillation frequency. It was anticipated that alcohol consumption would increase the oscillation frequency of the experimental groups‟ participants.

DIFFERENTIALLY-RELATED EFFECTS

The difference in alteration frequency between high and low sensitivity steering did not show any significant group, time of day or gender effects, nor any interaction effects between these variables.

TASK-RELATED EFFECTS

Task-related averages too, demonstrate non-significant findings across all group comparisons and throughout all independent variables, covariates and interactions thereof.

Summary of performance results

Table XI: Differential performance results.

DIFFERENTIAL PERFORMANCE			Alcohol vs Control				Alcohol vs Caffeine				Caffeine vs Control			
Dependent Test	Variable	Factor	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening
Accommod-ation	Reaction Time	S vs C	-	-	-	-	-	-	ALC ↓ p<0.03 *	p<0.03 *	CAF ↑ p<0.06	-	-	-
	Errors	S vs C	-	-	-	-	-	-	-	p<0.05 *	-	-	-	-
Visual Detection	Reaction Time (Median)	S vs C	ALC ↑ p<0.10 *	-	-	-	-	ALC ↓ p<0.07	ALC ↓ p<0.10	-	CAF ↑p<0.01 *	-	CAF ↑ p<0.08 *	-
	% Overlooked	S vs C	-	ALC ↑ p<0.10	ALC ↑ p<0.03	-	-	-	ALC ↑ p<0.05	-	-	-	-	□ p<0.09
	RTvs EX Correlation (ABS)	S vs C	-	-	-	ALC ↓ p<0.02 *	-	-	-	-	CAF ↑ p<0.04 *	CAF ↑ p<0.05 *	-	-
	RTvs EX Correlation (REL)	S vs C	-	-	-	□ p<0.10	-	-	-	□ p<0.06	-	-	-	-
Reading	Reading Speed	S vs C	-	-	-	-	-	-	-	-	-	-	-	-
	Errors Missed	S vs C	ALC ↑ p<0.10	-	-	-	ALC ↑ p<0.08	ALC ↑ p<0.06	ALC ↓ p<0.02 *	-	-	-	-	□ p<0.05
Memory	% Correct	S vs C	-	ALC ↑ p<0.03 *	-	-	-	-	-	-	-	-	CAF ↑ p<0.04	-
		60/90	-	-	-	-	-	-	-	-	-	-	-	-
		SC x 60/90	-	-	-	-	-	-	-	-	-	-	-	-
	Response Delay	S vs C	ALC ↑ p<0.09 *	-	-	-	-	ALC ↑ p<0.04 *	-	□ p<0.01	CAF ↑ p<0.01 *	-	CAF ↑ p<0.05 *	□ p<0.03
		60/90	-	ALC ↑ p<0.06	-	-	-	ALC ↓ p<0.03	-	-	CAF ↓ p<0.05	-	-	-
		SC x 60/90	-	-	-	-	ALC ↓ p<0.10	-	-	-	-	-	CAF ↑ p<0.03	-
Stimulus Response	Reaction Time	MTRPROG	-	-	-	-	-	-	-	-	-	-	-	-
		MTRPROG x SIZE	ALC ↑ p<0.06 *	-	-	-	-	-	-	-	-	CAF ♂↓ ♀↑ p<0.10	-	□ p<0.06
	Target Deviation	MTRPROG	-	-	-	-	-	-	-	-	-	-	-	-
		MTRPROG x SIZE	-	-	-	-	-	-	-	□ p<0.09	-	-	CAF↑ p<0.01 *	□ p<0.08
Driving Simulator	Info capacity	S vs C	-	ALC ↓ p<0.10 *	-	-	ALC ↓ p<0.07 *	ALC ↓ p<0.03	ALC ↓ p<0.09	-	CAF ↑p<0.03 *	CAF ↑ p<0.05 *	CAF ↑ p<0.01	□ p<0.03
	Alteration Frequency	S vs C	-	-	-	-	-	-	-	-	-	-	-	□ p<0.07

ALC = alcohol group CAF = caffeine group ↑ = Increase/ Higher ↓ = Decreased/ Lower ♀ = Female ♂ = Male □ = Interaction effect * = Effect without time Alcohol = Significant difference p<0.05 (-) = p<0.20

Table XII: Task-related performance results.

TASK EFFECTS		Alcohol vs Control				Alcohol vs Caffeine				Caffeine vs Control			
Dependent Test	**Variable**	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening
Accommod-ation	Reaction Time	ALC ↑ p<0.01	-	-	-	-	-	-	-	CAF ↑ p<0.01	-	-	-
	Errors	-	-	-	-	-	-	-	-	-	-	-	-
Visual Detection	Reaction Time (Median)	-	ALC ↑ p<0.04	-	□ p<0.04	ALC ↓ p<0.09	-	-	□ p<0.03	CAF ↑ p<0.02	-	CAF ↑ p<0.08	-
	% Overlooked	ALC ↑ p<0.01	ALC ↑ p<0.04 *	-	-	-	-	-	-	CAF ↑ p<0.03	CAF ↑ p<0.07	-	-
	RTvs EX Correlation (ABS)	-	-	-	-	-	-	-	-	-	-	-	-
	RTvs EX Correlation (REL)	-	ALC ↑ p<0.05 *	-	-	-	-	-	-	-	-	-	-
Reading	Reading Speed	-	-	-	-	-	-	-	-	-	-	-	-
	Errors Missed	ALC ↑ p<0.01	-	-	-	ALC ↑ p<0.04	-	-	-	-	-	-	-
Memory	% Correct	ALC ↓ p<0.08	-	ALC ↓ p<0.03	-	-	-	-	-	CAF ↑ p<0.05	-	-	-
	60-90	-	-	-	-	-	-	-	-	-	-	-	-
	Response Delay	-	ALC ↑ p<0.04	-	-	-	ALC ↓ p<0.10	-	-	-	-	-	-
	60-90	-	-	-	-	-	-	-	-	-	-	-	-
Stimulus Response	Reaction Time	-	-	ALC ↑E p<0.08	-	-	-	-	□ p<0.06	-	-	CAF ↑ p<0.08	-
	SIZE	-	-	-	□ p<0.08	-	-	-	-	CAF ↓ p<0.09	-	-	-
	Target Deviation	ALC ↑ p<0.01	-	-	-	-	ALC ♂ ↓ ♀ ↑ p<0.06	-	-	CAF ↑ p<0.01	-	-	-
	SIZE	ALC ↑ p<0.01	-	-	ALC ↑ p<0.03	-	-	-	-	-	-	-	-
Driving Simulator	Info capacity	-	-	-	-	-	-	-	-	CAF ↓ p<0.09	-	-	-
	Alteration Frequency	-	-	-	-	-	-	-	-	-	-	-	-

ALC = alcohol group CAF = caffeine group ↑ = Increase/ Higher ↓ = Decreased/ Lower ♀ = Female ♂ = Male E = Evening □ = Interaction effect * = Effect without time Alcohol = Significant difference p<0.05 (-) p<0.20

PHYSIOLOGICAL PARAMETERS

Physiological data was recorded throughout experimentation and was sampled during each individual test battery. Physiological parameters measured included heart rate frequency, body temperature and heart rate variability (RMSSD, high and low frequency power). Due to the amount of data, it was decided to elaborate in this results section only on heart rate frequency, RMSSD and body temperature. For an extended overview of all statistical analysis refer to Table XIII - Table XVIII.

Figure 50 illustrates average heart rate frequency across all tasks performed, showing group differences. The *caffeine+alcohol* group recorded the highest heart rate in four of the six tasks, illustrating the stimulating effects of caffeine.

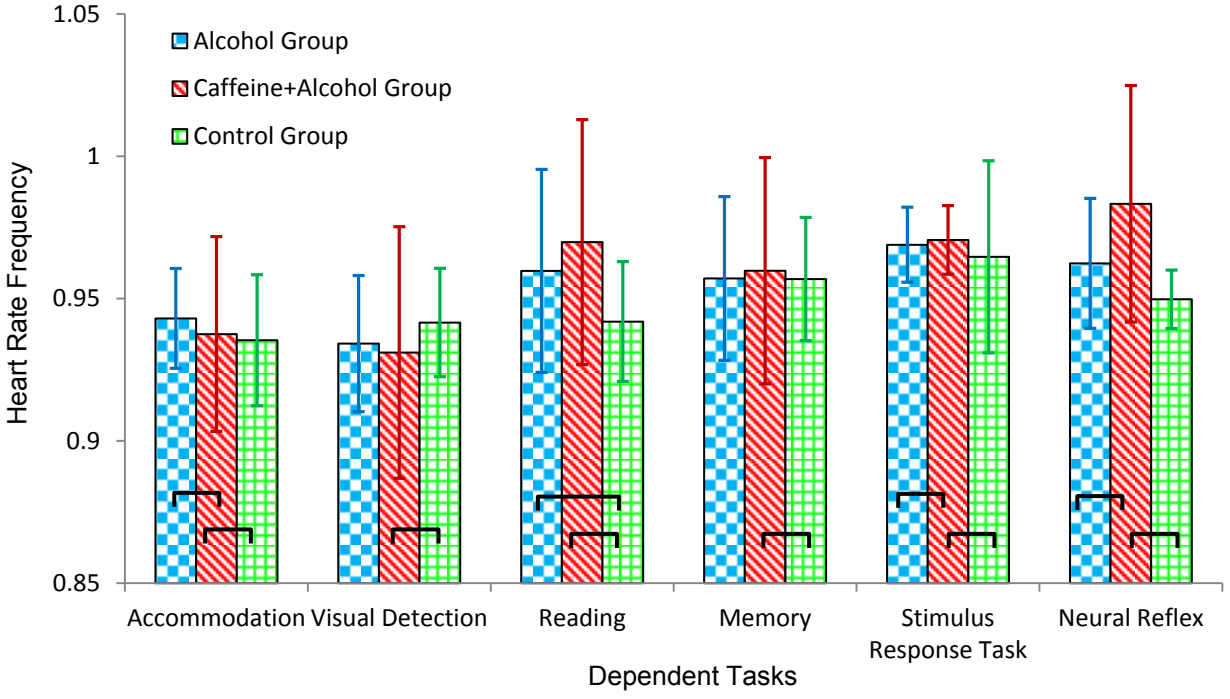

Figure 50: Relative heart rate frequency for all dependent tasks (significant difference, $p<0.05$ denoted by ⌐¬): Error bars denote standard deviation.

Comparisons between the *caffeine+alcohol* and *control* groups revealed significant differences across all dependent tasks ($p<0.05$). Few significant differences were observed between the *alcohol* and *control* groups, with the reading task being the only task to show a significant difference (F (2, 136) = 4.07, $p<0.02$). Statistical analysis between the experimental groups showed significant differences in the accommodation

and both motor tasks (stimulus response and neural reflex) with a statistical power of (F (2, 136) = 5.55, p<0.01), (F (2, 136) = 5.11, p<0.01) and (F (2, 136) = 5.95, p<0.01) respectively.

Visual Perceptual Performance

Accommodation Task

Heart rate frequency

DIFFERENTIALLY-RELATED EFFECTS

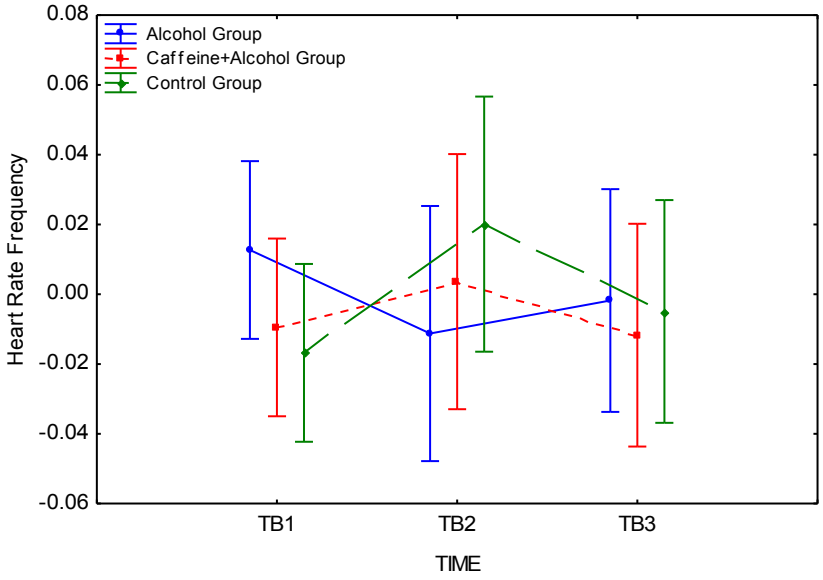

Figure 51: Relative effect of visual accommodation on heart rate frequency (*alcohol* vs. *control:* F (2, 136) = 4.00, p<0.03). Vertical bars denote 95% confidence intervals.

Figure 51 depicts a significant difference in heart rate between simple and complex accommodation observed between the *alcohol* and *control* groups (F (2, 136) = 4.00, p<0.03). The difference shows alcohol consumption to decrease the heart rate difference between complexities when compared to the *control* group. This relationship indicates that the *alcohol* group's heart rate was significantly lower than the *control* group during complex accommodation. The *caffeine+alcohol* group experienced an increase in heart rate during the complex task from TB1 to TB2; this result is opposite to the pure alcohol trial, which experienced a reduction in heart rate after the introduction of alcohol. The stimulant properties of caffeine therefore override the depressant effects of alcohol consumption.

TASK-RELATED EFFECTS

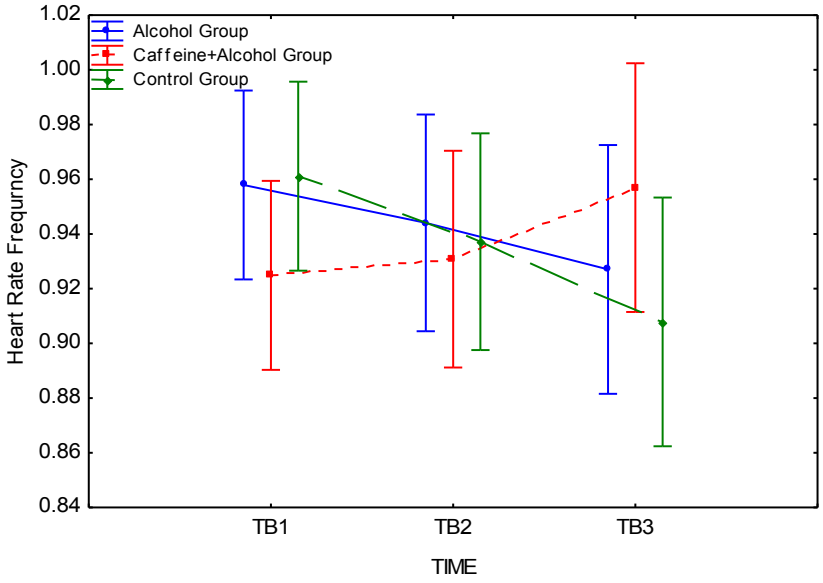

Figure 52: Relative heart rate frequency during a choice reaction task (*alcohol* vs. *caffeine+alcohol*: F (2, 136) = 5.55, p<0.01, *caffeine+alcohol* vs. *control*: *F* (2, 136) = 7.74, p<0.01). Vertical bars denote 95% confidence intervals.

Alcohol consumption imposed a significantly different heart rate between the *alcohol* and *caffeine+alcohol* as well as between caffeine+*alcohol* and the *control* groups (*F* (2, 136) = 5.55, p<0.01) and (*F* (2, 136) = 7.74, p<0.01), respectively. Average heart rate indicated that the *alcohol* and *control* groups displayed decreasing trends throughout testing; conversely, the *caffeine+alcohol* group's heart rate increased as a function of time (Figure 52).

Heart rate variability- RMSSD

DIFFERENTIALLY-RELATED EFFECTS

Heart rate variability between simple and complex accommodation yielded no significant differences between groups. Further, no significant differences were observed as a factor of time of day, between genders nor as an interaction of these two factors. Comparison between the *caffeine+alcohol* and *control* groups, revealed that the *caffeine+alcohol* group revealed a higher heart rate variability (*F* (1, 68) = 3.21, p<0.08), with a similar result observed for time of day (*F* (1, 68) = 3.41, p<0.07).

TASK-RELATED EFFECTS

Statistical analyses reveal a significant effect between the *caffeine+alcohol* and *control* groups (F (2, 136) = 5.79, p<0.01), with the former showing a substantially higher heart rate variability. Average heart rate variability functions, as indicated by Figure 53 show that the greatest variability in heart rate responses was elicited in the *alcohol* group while the lowest responses were found in the *control* group. The increase in heart rate variability experienced by the *alcohol* group suggests that the least amount of cognitive effort was invested during TB2.

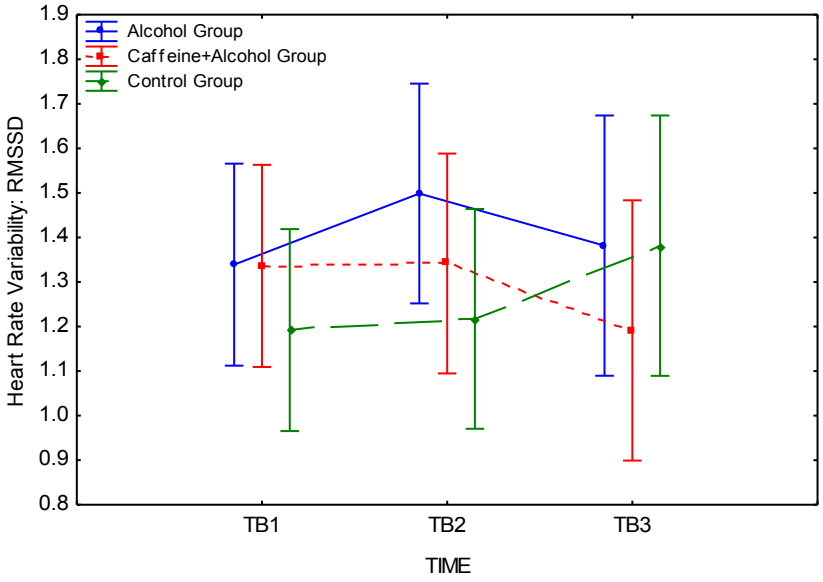

Figure 53: Relative heart rate variability during a choice reaction task (*caffeine+alcohol* vs. *control*: F (2, 136) = 5.79, p<0.01). Vertical bars denote 95% confidence intervals.

Body Temperature

Body temperature was quantified through skin and tympanic sampling methods. Tympanic temperature measures suffered technical defects and did not allow proper measurement for many participants. Consequently, analysis of the data forced tympanic temperature data to be excluded. Therefore, skin temperature will be elaborated upon and will form the basis for body temperature assessment.

DIFFERENTIALLY-RELATED EFFECTS

The difference in body temperature was relatively even between groups for changes in task complexity. No significant results were demonstrated for task complexity with regard

to body temperature between groups. A markedly different result was observed between the *alcohol* and *caffeine+alcohol* groups (F (2, 136) = 2.90, p<0.06). This difference between the *alcohol* and *caffeine+alcohol* groups is indicated by Figure 54. The consumption of alcohol increased the difference in skin temperature between simple and complex accommodation in the *alcohol* group, with a higher skin temperature during complex tasks. In contrast, skin temperature differences decreased in the *caffeine+alcohol* group, indicative of simple tasks eliciting higher temperatures.

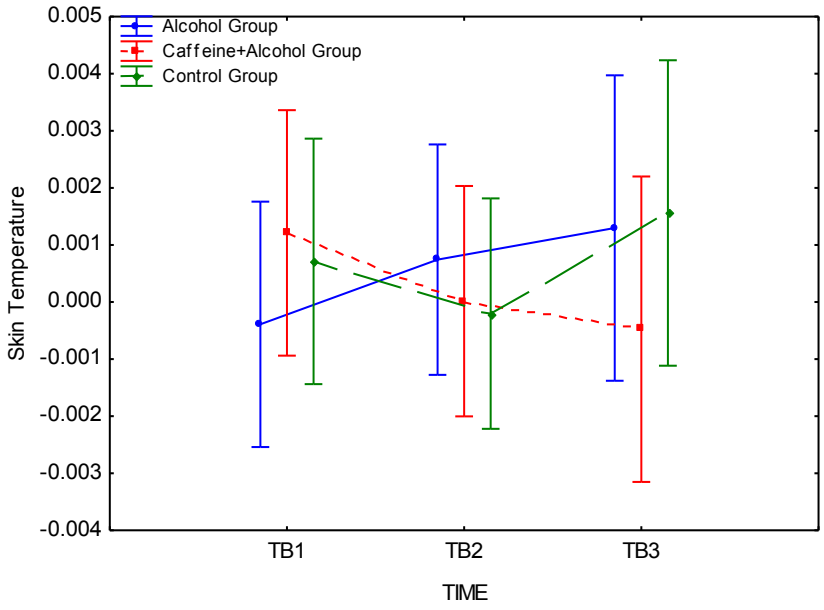

Figure 54: Relative effect of visual accommodation on skin temperature. Vertical bars denote 95% confidence intervals.

TASK-RELATED EFFECTS

No significant group effects were demonstrated for skin temperature during accommodation. A significant time of day effect is observed within the *alcohol* and *control* group comparison. (F (2, 136) = 3.7, p<0.03). Exemplified by Figure 55, the *control* groups' skin temperature (when compared to the alcohol group) was significantly higher during morning experimentation. Gender did not seem to have an effect on skin temperature, yielding non-significant group effects. Similarly no interaction effects were noticed.

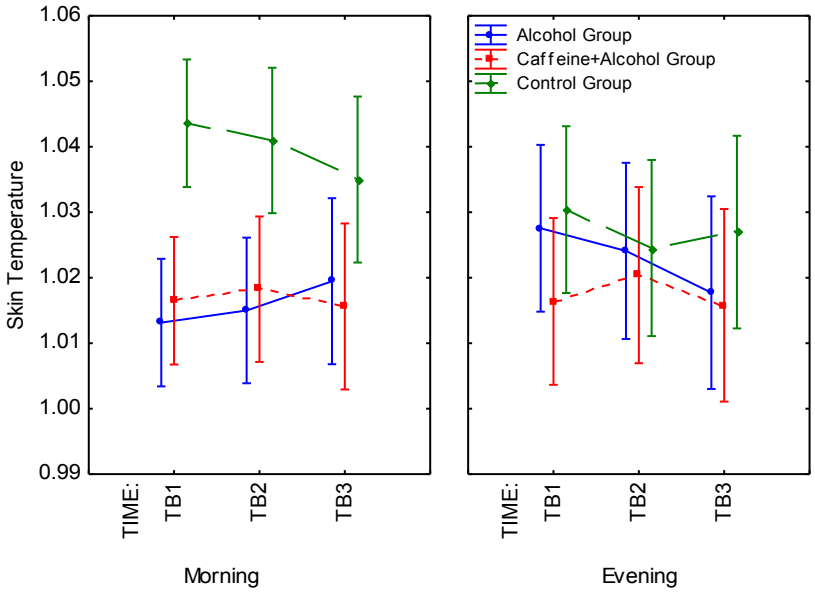

Figure 55: Relative skin temperature during a choice reaction task (*alcohol* vs. *control: F* (2, 136) = 3.7, p<0.03). Vertical bars denote 95% confidence intervals.

Visual Detection Task

Heart rate frequency

DIFFERENTIALLY-RELATED EFFECTS

The differences in complexity in the visual detection task did not impose significant effects on heart rate frequency. Furthermore, the same result was observed for time of day and gender effects between groups. All groups reflected lower heart rate frequencies during TB2 for complex visual detection, where after heart rate increased for complex visual detection and decreased for simple visual detection.

TASK-RELATED EFFECTS

A significant effect is observed between results for the *caffeine+alcohol* and *control* groups (*F* (2, 136) = 9.99, p<0.01), indicating that the combination of alcohol with caffeine has a profound effect on heart rate. No significant differences between the *alcohol* and *control* groups were observed, therefore, consumption of alcohol alone does not have an effect on heart rate frequency, when performing a visual detection task (Figure 50).

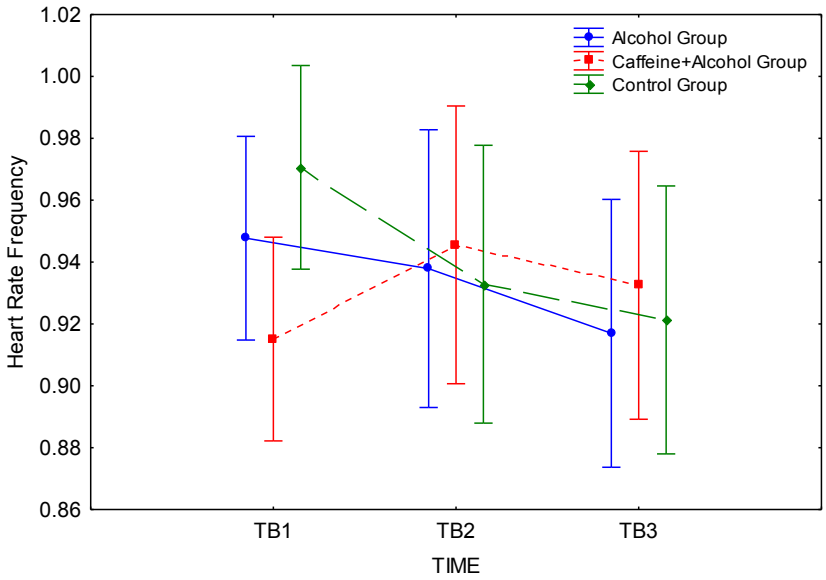

Figure 56: Relative heart rate frequency for a visual detection task (*caffeine+alcohol* and *control* groups (F (2, 136) = 9.99 p<0.01). Vertical bars denote 95% confidence intervals.

Some differences in heart rate were observed between the *alcohol* and *caffeine+alcohol* groups (F (2, 136) = 2.77, p<0.07) during the visual detection task. Unexpectedly, heart rate for the *caffeine+alcohol* group during TB1 (post caffeine ingestion) was lower than that of the *control* group. It would be expected for heart rate to have been higher after the consumption of caffeine.

Heart rate variability- RMSSD

DIFFERENTIALLY-RELATED EFFECTS

The effects of alcohol on heart rate variability did not yield any significant group results for the visual detection task. Furthermore, no significant findings were observed between groups as a factor of time of day. A significant effect of gender between the *alcohol* and *control* groups is however present (F (2, 110) = 3.62, p<0.03). Heart rate variability showed a greater complexity-related difference in the *alcohol* group for both male and female participants (Figure 57). The greatest difference in complexity-related heart rate variability was observed for the female participants in the *alcohol* group. Females from the *caffeine+alcohol* group incurred the next greatest complexity-related variability in heart rate. Therefore, the change in complexity affected female participants to a greater degree than male participants.

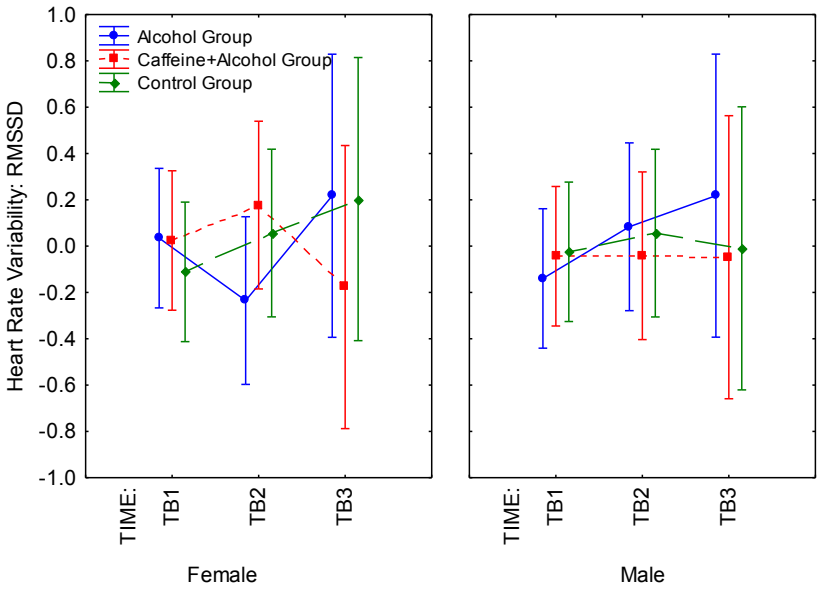

Figure 57: Relative effect of an increased information density during a visual detection task on skin temperature for males and females (*alcohol* vs. *control: F* (2, 110) = 3.62, p<0.03). Vertical bars denote 95% confidence intervals.

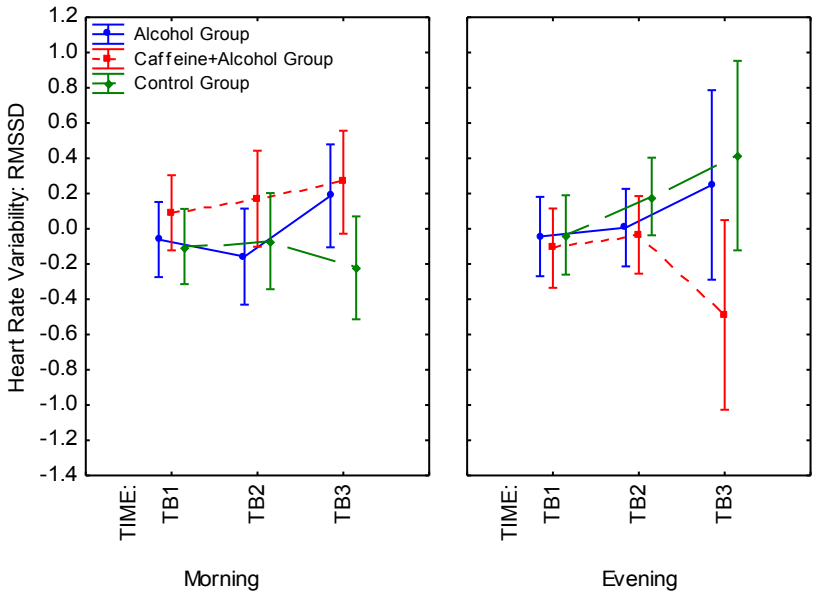

Figure 58: Relative effect of an increased information density during a visual detection task on skin temperature for morning and evening experimentation (*caffeine+alcohol* vs. *control: F* (1, 56) = 6.04, p<0.02). Vertical bars denote 95% confidence intervals.

A significant time of day effect was observed between the *caffeine+alcohol* and *control* groups (*F* (1, 56) = 6.04, p<0.02). Comparisons for morning experimentation between the *caffeine+alcohol* and the *control* groups were largely different to heart rate variability

during evening experimentation (Figure 58). The greatest difference in heart rate variability for simple vs. complex visual detection was found in the *alcohol* group during morning assessment. In contrast, the *caffeine+alcohol* group showed greater complexity-related variability in heart rate during evening experimentation. Therefore, during evening experimentation, the cognitive workload of the *caffeine+alcohol* group was lower than the *alcohol* participants and significantly lower than the *control* group.

TASK-RELATED EFFECTS

Alcohol consumption does not significantly change heart rate variability; however, the *alcohol* group did display reduced heart rate variability in comparison to the other groups tested, suggesting a higher cognitive workload and increased attention (Figure 59). The *caffeine+alcohol* group showed an opposing trend to that observed in the *alcohol* group, with variability of the heart beat decreasing during TB2 and TB3. Although these differences are noticed, there is no statistical backing to underpin these considerations.

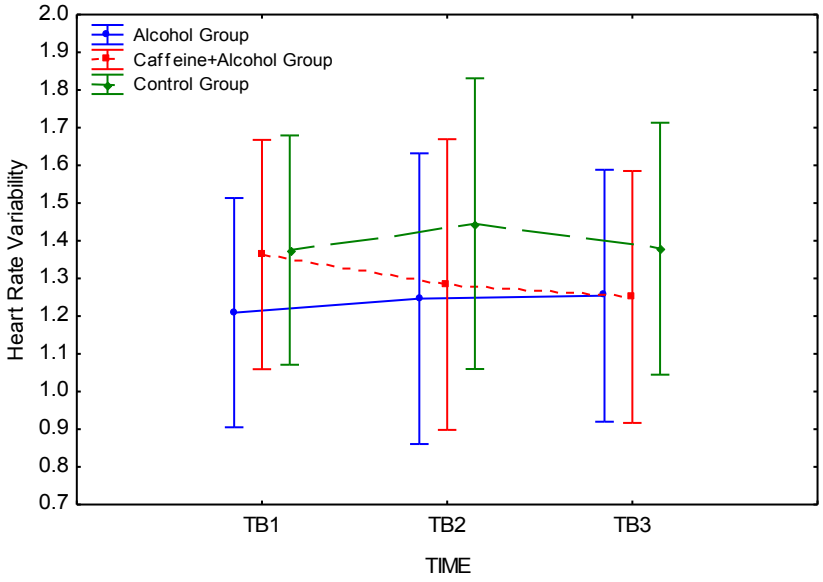

Figure 59: Relative heart rate variability for a visual detection task. Vertical bars denote 95% confidence intervals.

No significant differences in heart rate variability were noticed for the time of day at which the visual detection task was conducted. Comparison between the *alcohol* and *control* groups demonstrated a difference in heart rate variability as a factor of time of day (F (2, 110) = 2.73, $p<0.07$). Similarly, a marked difference in gender-related performance was also observed between these groups (F (2, 110) = 3.62, $p<0.06$). This suggests that the

caffeine consumption had little antagonistic effect on heart rate variability during a visual detection task.

Body Temperature

DIFFERENTIALLY-RELATED EFFECTS

The comparison of difference in skin temperature between simple and complex visual detection between *alcohol* and *caffeine+alcohol* group temperature proves this difference to be statistically significant (F (2, 136) = 3.70, p<0.03). The combination of caffeine and alcohol consumption produced an increase in skin temperature for complex visual detection throughout experimentation. Conversely, pure alcohol consumption initially caused an increase in temperature for complex visual detection. However, during TB3, skin temperature for the complex task decreased. Skin temperature during the visual detection did not change significantly between all groups for simple and complex task performance. No significant effects were demonstrated in the respective control group and experimental group comparisons.

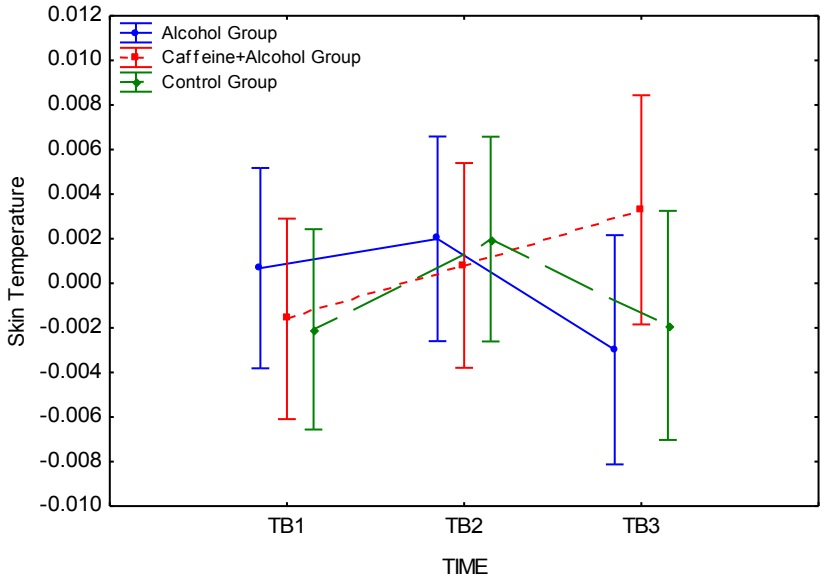

Figure 60: Relative effect of an increased information density during a visual detection task on skin temperature for skin temperature (*alcohol* vs. *caffeine+alcohol*: F (2, 136) = 3.70, p<0.03). Vertical bars denote 95% confidence intervals.

TASK-RELATED EFFECTS

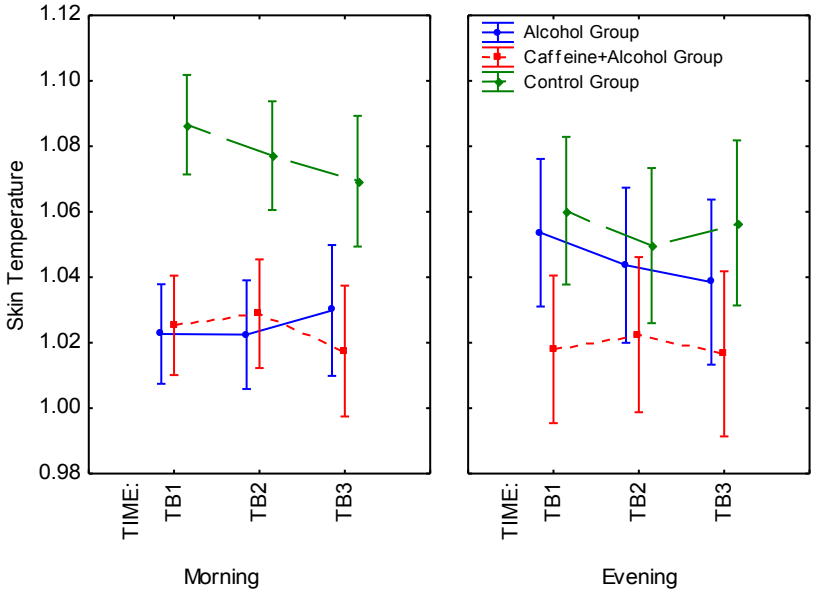

Figure 61: Relative skin temperature for a visual detection task (*alcohol* and *control: F* (2, 136) = 4.89, p<0.03, *alcohol* and *caffeine+alcohol: F* = (2, 136) = 3.64, p<0.03). Vertical bars denote 95% confidence intervals.

No significant group effects were found for skin temperature, nor were any gender effects present for skin temperature between groups. Examination of skin temperature as a factor of time of day effects reveals a significant effect found between the *alcohol* and *control* groups (*F* (2, 136) = 4.89, p<0.03), demonstrating that after the ingestion of alcohol a decrease in temperature resulted (Figure 61). Similarly, an interaction between skin temperature as a factor of time of day was observed between the *alcohol* and *caffeine+alcohol* groups (*F* = (2, 136) = 3.64, p<0.03). The combined consumption of caffeine and alcohol resulted in an initial increase in temperature post- alcohol consumption, followed by a decreased temperature - this was observed in both morning and evening experimental sessions.

A numerical gender effect was detected between the *caffeine+alcohol* and the *control* groups (*F* (2, 136) = 2.73, p<0.07), the *control* group recording the higher temperatures in both sexes.

Reading Task

Heart rate frequency

DIFFERENTIALLY-RELATED EFFECTS

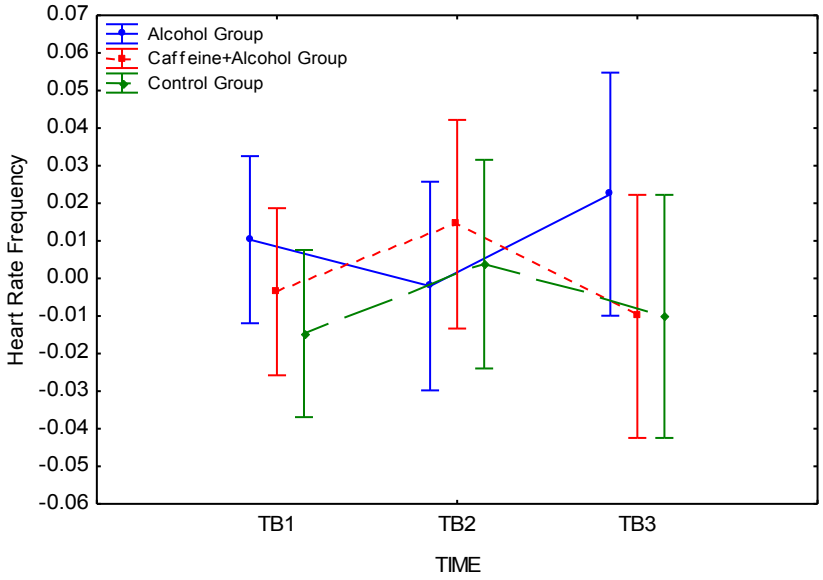

Figure 62: Relative effect of an increased visual pattern recognition difficulty on heart rate frequency. Vertical bars denote 95% confidence intervals.

Alcohol did not impose significant changes on heart rate during the reading task. This held true for time of day as well as for gender differences. The *control* and *caffeine+alcohol* groups displayed a relationship indicative of low- resolution reading causing an elevation in heart rate. Unlike these groups, the *alcohol* group during TB1 showed a lower heart rate for high resolution reading. Post- alcohol ingestion, this relationship changed and heart rate was reduced during low resolution reading (Figure 62).

TASK-RELATED EFFECTS

The average group functions of heart rate frequency are shown in (Figure 63). Alcohol consumption (as indicated by the *alcohol* group) resulted in a significantly higher heart rate during TB2 and TB3, when compared to the *control* group (F (2, 136) = 4.07, $p<0.02$). Similarly, heart rate elicited in the *caffeine+alcohol* group was significantly higher than the *control* group at these same stages (F (2, 136) = 11.67, $p<0.01$). Collectively, alcohol consumption increased heart rate immediately post- alcohol ingestion and was maintained at this level during TB3.

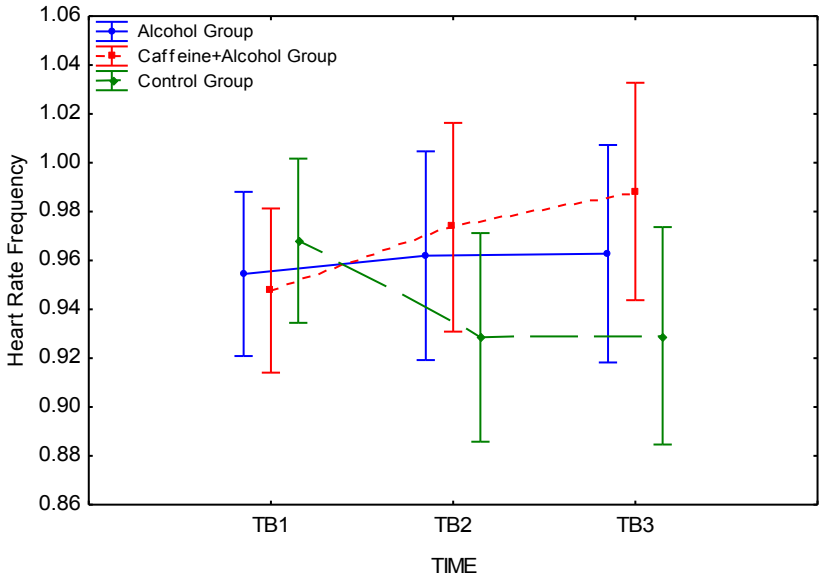

Figure 63: Relative heart rate frequency during a reading task (*alcohol* vs. *control: F* (2, 136) = 4.07, p<0.02)*, caffeine+alcohol* vs. *control: F* (2, 136) = 11.67, p<0.01). Vertical bars denote 95% confidence intervals.

Heart rate variability- RMSSD

DIFFERENTIALLY-RELATED EFFECTS

RMSSD did not show any significant alcohol effects for general complexity-related reading.

The difference in reading complexity as a factor of gender yielded a significant effect when comparison between the *alcohol* and *control* group was made (*F* (1, 68) = 4.19, p<0.03). Similarly, the *alcohol* group when compared to the *caffeine+alcohol* group showed a significant gender-related effect too (*F* (1, 68) = 5.71, p<0.03). Heart rate variability whilst reading was higher for female participants (Figure 64). The greatest difference between high and low resolution reading for heart rate variability was observed in female *alcohol* participants during TB2. Conversely, the male participants from this same group and at the same stage of testing produced the lowest complexity-related difference in heart rate variability. In comparison to the *control* group, the *alcohol* group had a higher difference in complexity-related heart rate variability.

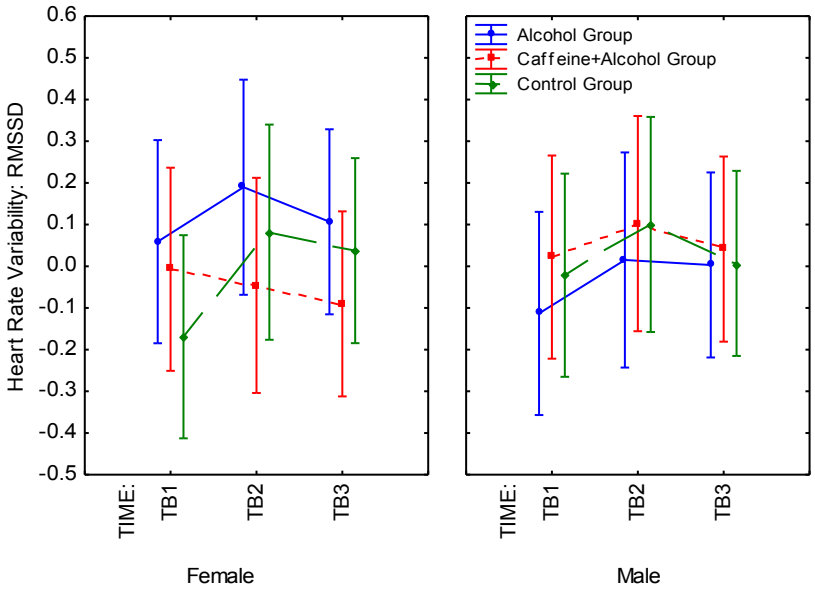

Figure 64: Relative effect of an increased visual pattern recognition difficulty on heart rate variability for males and females (*alcohol* vs. *control:* F (1, 68) = 4.19, p<0.03, *alcohol* vs. *caffeine+alcohol:* F (1, 68) = 5.71, p<0.03). Vertical bars denote 95% confidence intervals.

TASK-RELATED EFFECTS

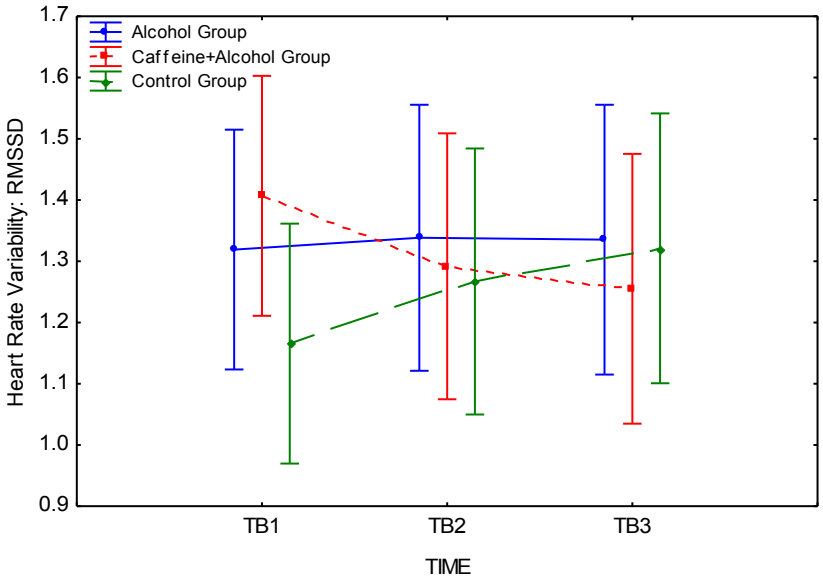

Figure 65: Relative heart rate variability during a reading task (*caffeine+alcohol* vs. *control:* F (2, 134) = 5.23, p<0.01). Vertical bars denote 95% confidence intervals.

The change in heart rate variability was significantly greater in the *caffeine+alcohol* group when compared to the *control* group (F (2, 134) = 5.23, p<0.01). Comparison between results for the *alcohol* and *control* groups yields no significant differences. Alcohol

consumption (pure) caused the difference in high and low resolution reading heart rate variability to increase (Figure 65). Cognitive workload, indirectly measured through RMSSD, was lower in the *alcohol* group post- alcohol ingestion, when compared to the *caffeine+alcohol* and *control* groups. Throughout testing, the *control* group consistently utilised a higher cognitive workload as indicated by the lower heart rate variability. These findings are suggestive of alcohol consumption and caffeine+alcohol consumption being detrimental to heart rate variability and hence cognitive workload.

A significant difference between heart rate variability in morning performance compared to evening performance was observed between the *alcohol* and *caffeine+alcohol* groups (F (2, 134) = 3.25, $p<0.05$) (Figure 66). The RMSSD functions of the *alcohol* and *caffeine+alcohol* groups were distinctly different in both morning and evening performance. During morning performance the *alcohol* group"s heart rate variability was higher than the *caffeine+alcohol* group; however, in evening experimentation, this difference was reversed, with the *caffeine+alcohol* group incurring the highest variability in heart rate (Figure 66). It appears that the combination of caffeine and alcohol produced a greater effect on heart rate variability in morning experimentation.

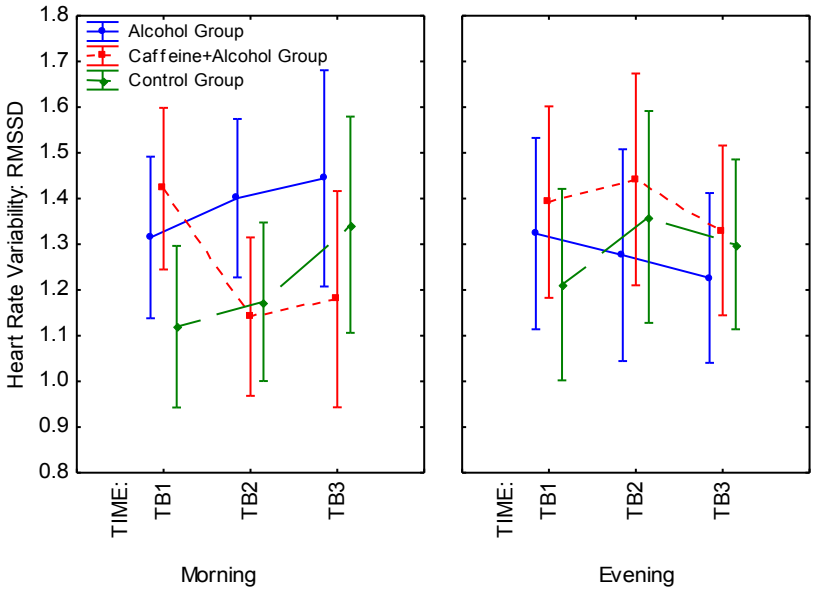

Figure 66: Relative heart rate variability during a reading task for morning and evening experimentation (*alcohol* vs. *caffeine+alcohol: F* (2, 134) = 3.25, $p<0.05$). Vertical bars denote 95% confidence intervals.

Body Temperature

DIFFERENTIALLY-RELATED EFFECTS

The reading task imposed no significant changes in body temperature.

TASK-RELATED EFFECTS

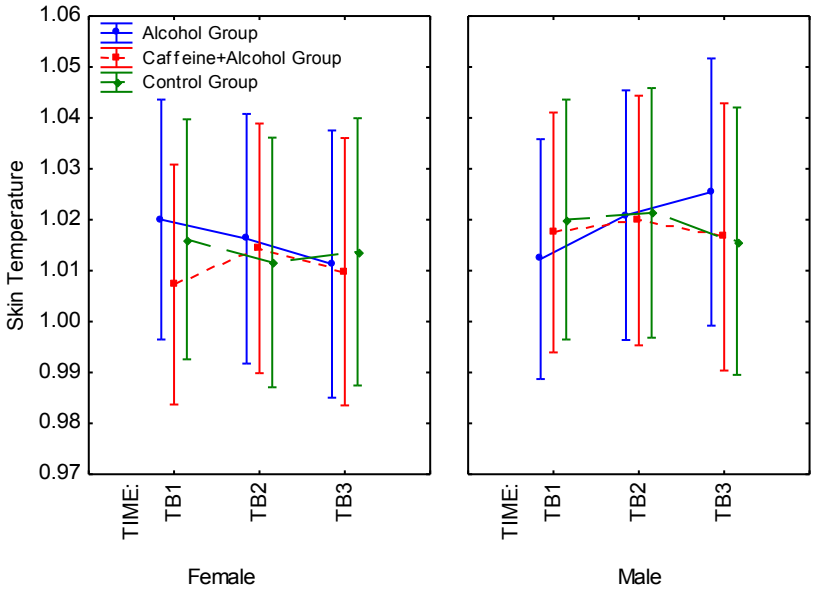

Figure 67: Relative skin temperature during a reading task (*alcohol* vs. *caffeine+alcohol: F* (2, 136) = 3.10, p<0.05). Vertical bars denote 95% confidence intervals.

The average function of skin temperature did not yield significant main effects of *alcohol* and *caffeine+alcohol*. Comparison between the *alcohol* and *caffeine+alcohol* groups indicates that temperature was higher in the *alcohol* group for both male and female participants (*F* (2, 136) = 3.10, p<0.05).

Memory Performance

Memory Recall Task

Heart rate frequency

DIFFERENTIALLY-RELATED EFFECTS

Alcohol consumption, as well as the combined consumption of alcohol and caffeine, when compared to the *control* group, effected significant differences in heart rate between simple and complex memory recall (*F* (1, 67) =9.78, p< 0.01) and (*F* (1, 67) = 7.60, p<0.01) respectively. Figure 68 depicts group comparisons for heart rate frequency during simple vs. complex memory recall. In both instances the *alcohol* and *caffeine+alcohol*

groups experienced an increased difference in heart rate between five- and seven-number recall, demonstrating the impact of alcohol on heart rate during a memory task. Furthermore, the positive function demonstrated by both experimental groups throughout experimentation, indicated that the difference between simple and complex recall shows a higher heart rate during complex memory recall. Conversely, memory recall for five numbers showed a reduction in heart rate when compared to complex recall.

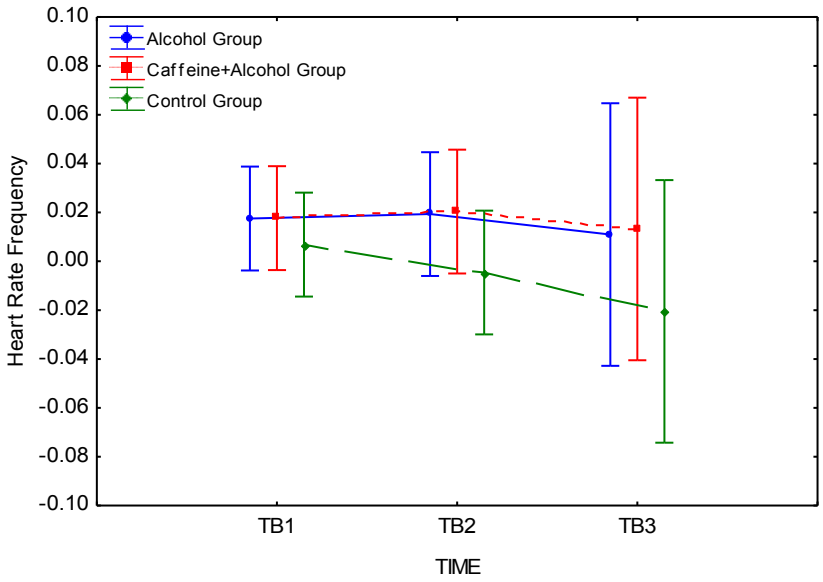

Figure 68: Relative effect of an increased memory capacity demand on heart rate frequency (*alcohol* vs. *control*: F (1, 67) =9.78, p< 0.01), *caffeine+alcohol* vs. *control:* F (1, 67) = 7.60, p<0.01). Vertical bars denote 95% confidence intervals.

Heart rate frequency seems to be sensitive to the time of day at which the memory task was conducted. Comparison between the *caffeine+alcohol* and the *control* groups, shows a significant difference for the time of day at which testing occurred (F (2, 134) = 3.80, p<0.03). This result is largely attributable to the difference between these groups during evening experimentation (Figure 69).

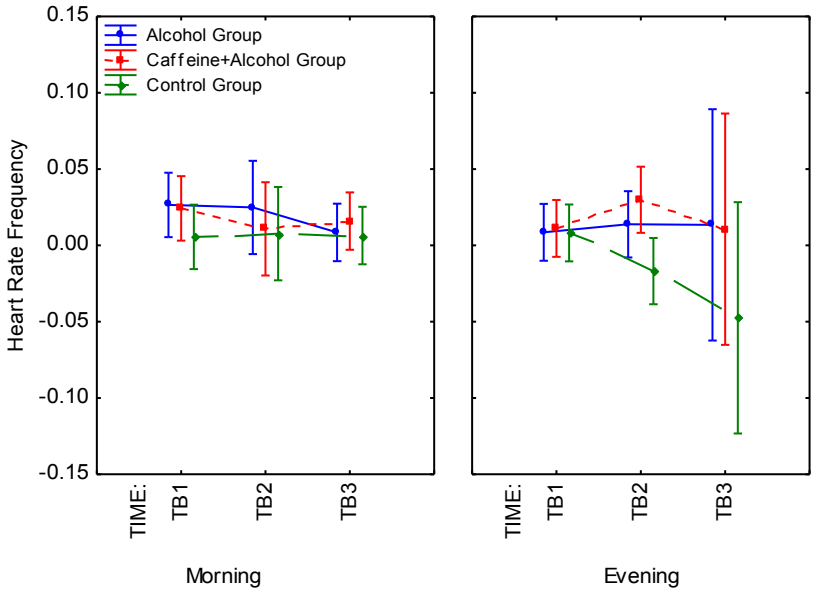

Figure 69: Relative effect of an increased memory capacity demand on heart rate frequency for morning and evening experimentation (*caffeine+alcohol* vs. *control*: F (2, 134) = 3.80, p<0.03). Vertical bars denote 95% confidence intervals.

Analysis of heart rate frequency for long term vs. short term rehearsal during the memory recall is displayed in Figure 70. Rehearsal time comparisons demonstrate significant differences between the *alcohol* and *caffeine+alcohol* as well as between the *caffeine+alcohol* and *control* groups (F (2, 136) = 3.79, p<0.03) and (F (2, 134) = 17.86, p<0.01) respectively. The *alcohol* vs. *caffeine+alcohol* comparison indicates that the *caffeine+alcohol* group demonstrated a larger difference in heart rate between five- and-seven number recalls, in both short term and long term rehearsal. The combination of prior caffeine consumption with alcohol consumption significantly increased the difference between simple and complex memory recall, in both short and long term rehearsal.

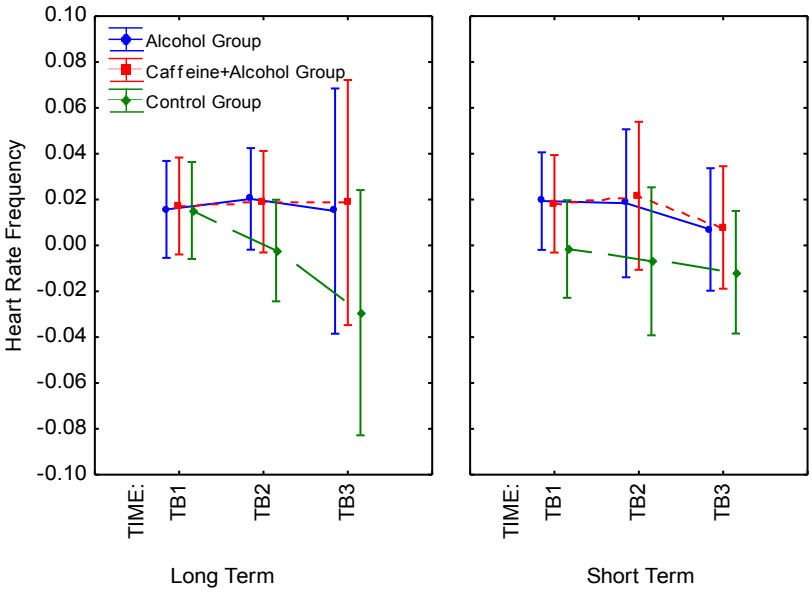

Figure 70: Relative effect of an increased memory rehearsal time on heart rate frequency (*alcohol* vs. *caffeine+alcohol*: F (2, 136) = 3.79, $p<0.03$), *caffeine+alcohol* vs. *control*: F (2, 134) = 17.86, $p<0.01$). Vertical bars denote 95% confidence intervals.

TASK-RELATED EFFECTS

As indicated in Figure 50, average heart rate for the *caffeine+alcohol* group was significantly higher than the *control* group for the memory task (F (2, 134) = 14.18, $p<0.01$). The memory task elicited no other significant changes in heart rate, inclusive of effects for time of day, gender, short term and long term rehearsal and any interaction between these factors.

Heart rate variability- RMSSD

DIFFERENTIALLY-RELATED EFFECTS

Alcohol consumption did not impose significant changes on heart rate variability; this result was true for all group comparisons and for time of day effects.

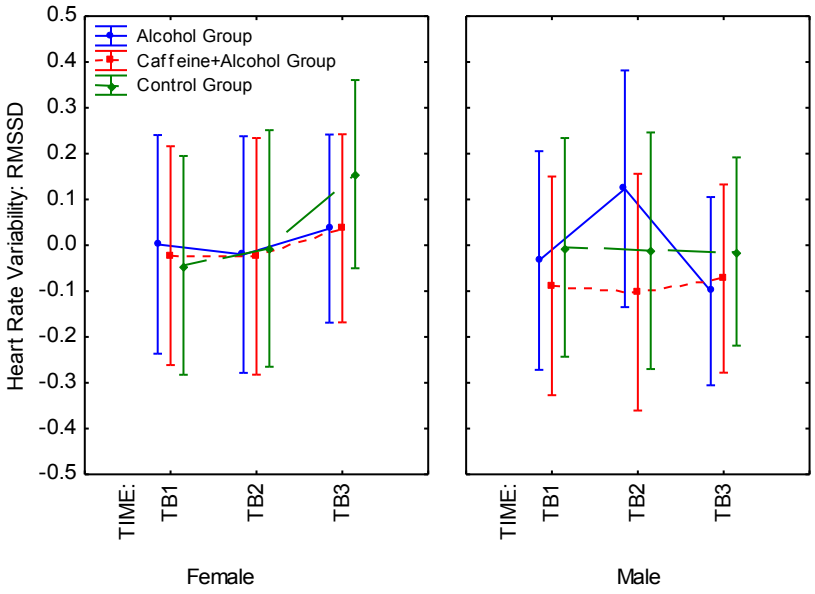

Figure 71: Relative effect of an increased memory capacity demand on heart rate variability. Vertical bars denote 95% confidence intervals.

A numerical difference between male and female participants is observed between the *alcohol* and *control* comparisons (F (2, 132) = 2.98, p<0.06) (Figure 71). In this scenario, the male participants from the *alcohol* group demonstrated greater differences in simple vs. complex heart rate variability. The difference between the *alcohol* and *control* groups is largely attributable to this increased difference in male *alcohol* participants.

A significant effect of rehearsal time is observed for comparisons of *alcohol* vs. *control* (F (2, 132) = 3.07, p<0.05) and *caffeine+alcohol* vs. *control*: F (2, 132) = 6.93, p<0.01). Figure 72 exemplifies that all groups tested experienced a greater difference in heart rate variability during short term rehearsal when compared to long term rehearsal. This suggests that alcohol consumption changes the cognitive effort invested in the memory task and as a result effort varies to a greater degree for short term rehearsal and is more consistent for long term rehearsal.

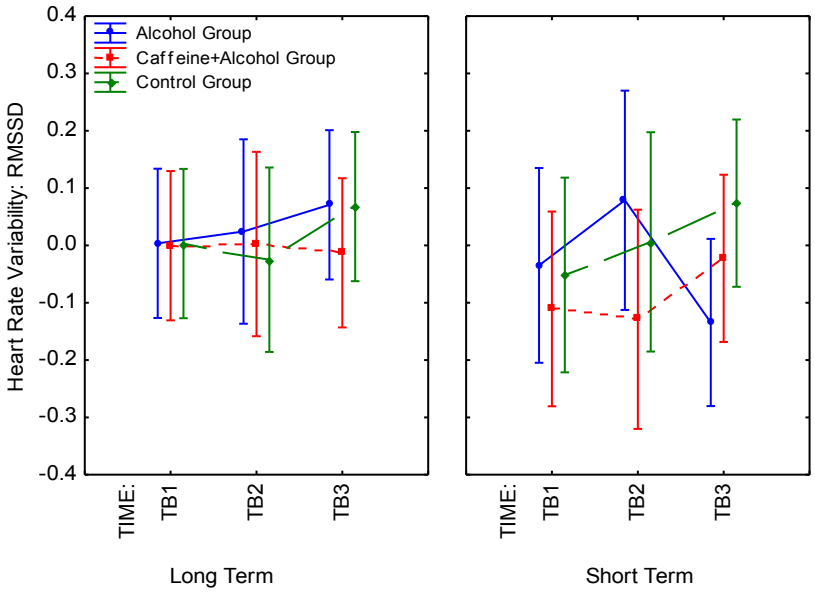

Figure 72: Relative effect of an increased memory rehearsal time on heart rate variability (*alcohol* vs. *control*: F (2, 132) = 3.07, p<0.05), *caffeine+alcohol* vs. *control*: F = (2, 132) = 6.93, p<0.01). Vertical bars denote 95% confidence intervals.

TASK-RELATED EFFECTS

Heart rate variability did not provide any statistical group differences. Further, no effects for time of day or gender-related differences were recorded through heart rate variability for the memory task. Comparisons of short term and long term rehearsal time also failed to yield statistical significance.

Body Temperature

DIFFERENTIALLY-RELATED EFFECTS

The effect of alcohol resulted in a significantly higher skin temperature when compared to the *control* group (F (2, 136) = 3.40, p<0.04). No significant changes in skin temperature were observed when caffeine was consumed prior to alcohol; the caffeine+alcohol group did however demonstrate a marginal increase in temperature (Figure 73).

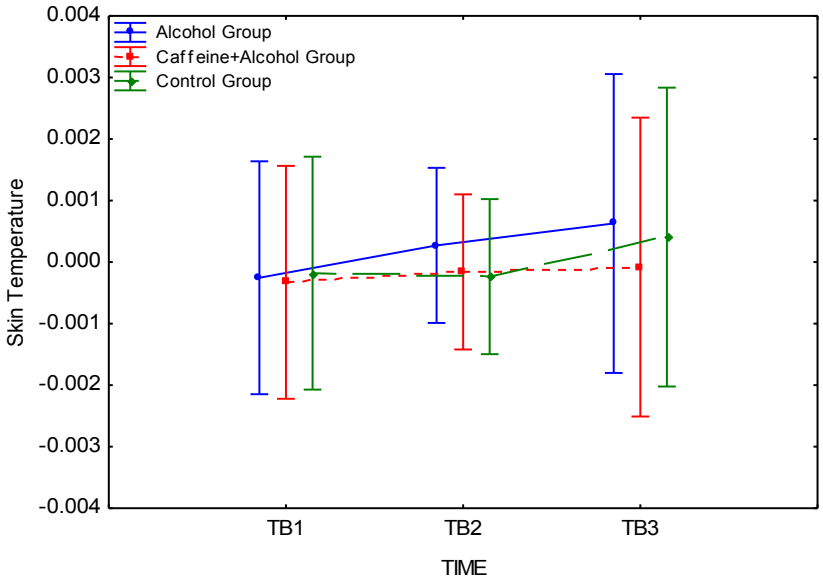

Figure 73: Relative effect of an increased memory capacity demand on skin temperature (*alcohol* vs. *control: F* (2, 136) = 3.40, p<0.04). Vertical bars denote 95% confidence intervals.

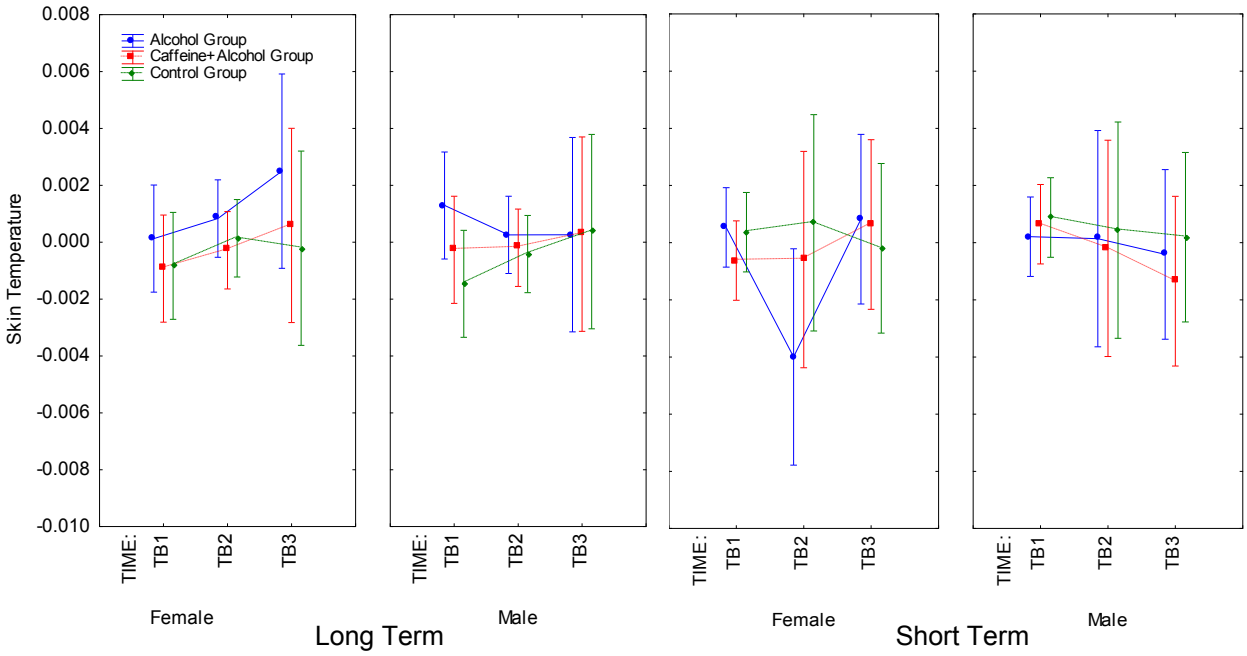

Figure 74: Relative effect of an increased memory rehearsal time on skin temperature for males and females (*alcohol* vs. *control: F* (2, 136) = 3.95, p<0.03). Vertical bars denote 95% confidence intervals.

Complexity-related skin temperature results for the *alcohol* and *caffeine+alcohol* comparison show a main interaction effect between rehearsal time and gender (*F* (2, 136) = 3.95, p<0.03). This interacting effect demonstrates that pure alcohol consumption

increased temperature for both male and female participants during long term rehearsal. Further, short term rehearsal saw female *alcohol* group participants produce the greatest difference between simple and complex skin temperature, while the male *caffeine+alcohol* group participants recorded a higher temperature than the male participants from the *alcohol* group.

TASK-RELATED EFFECTS

Average temperature between groups did not show any significant changes across group comparisons, inclusive of time of day and gender effects.

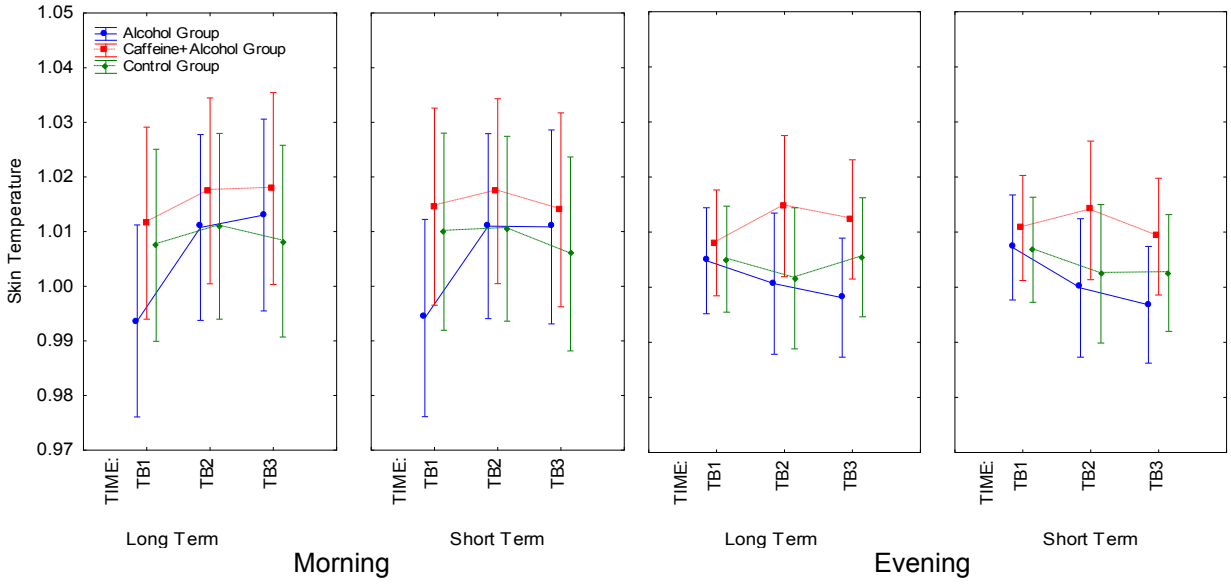

Figure 75: Relative skin temperature during a memory recall task (*alcohol* vs. *control: F* (1, 68) = 9.40, p<0.01). Vertical bars denote 95% confidence intervals.

Skin temperature for the *alcohol* and *control* comparison shows a main interaction effect between rehearsal time and time of day (*F* (1, 68) = 9.40, p<0.01). The *alcohol* group produced significantly lower temperature results for both short and long term rehearsal during morning and evening experimentation in comparison to the *control* (Figure 75).

Motor Performance

Stimulus Response Task

The stimulus response task was performed once per test battery and combined both simple and complex parameters into one test. As a result, physiological data was recorded and analysed as task-related effects only. The physiological results will therefore be discussed, describing the overall responses of simple and complex task performance. In

an attempt to comprehensively cover this task, High Frequency and Low Frequency Power will be discussed in conjunction with RMSSD.

Heart rate frequency

TASK-RELATED EFFECTS

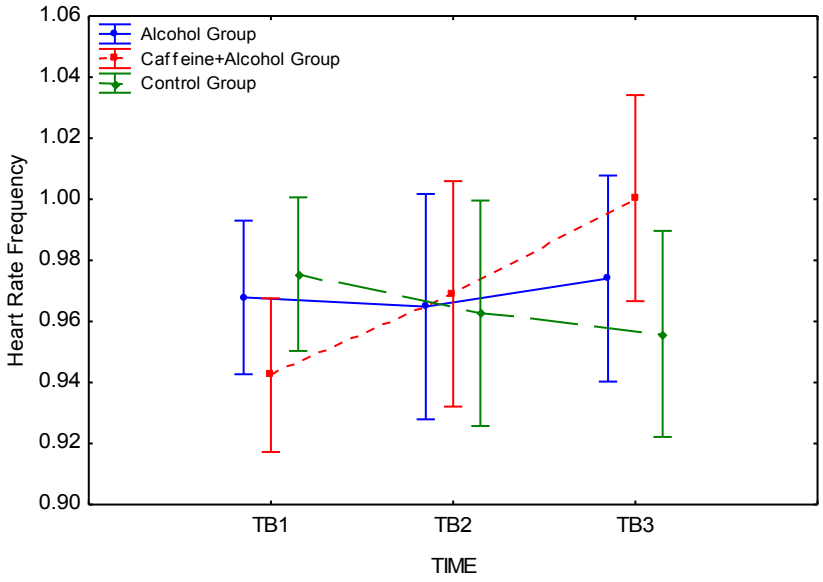

Figure 76: Relative heart rate frequency during a Fitt‟s task (*alcohol* vs. *caffeine+alcohol: F* (2, 136) = 5.11, p<0.01, *caffeine+alcohol* vs. *control: F* (2, 136) = 10.32, p<0.01). Vertical bars denote 95% confidence intervals.

The difference between the two experimental groups is statistically different, with the *caffeine+alcohol* group recording a significantly higher heart rate post- alcohol ingestion (*F* (2, 136) = 5.11, p<0.01). Additionally and as illustrated in Figure 50, the *caffeine+alcohol* group when compared to the *control* group, also recorded a significantly higher heart rate (*F* (2, 136) = 10.32, p<0.01). Average heart rate frequency post *alcohol* ingestion was highest in the *caffeine+alcohol* group, with the *alcohol* group recording the second- highest heart rate.

Significant effects were observed for heart rate as a function of time of day in comparisons between *alcohol* and *control* groups (*F* (1, 68) = 5.49, p<0.03) and between the *caffeine+alcohol* and *control* groups (*F* (1, 68) = 5.24, p<0.03). Heart rates for the experimental groups post- TB2 were significantly higher than the *control* group during the morning and significantly lower during evening experimentation (Figure 77). The

combination of caffeine and alcohol consumption demonstrated a higher heart rate when compared to the pure *alcohol* participants.

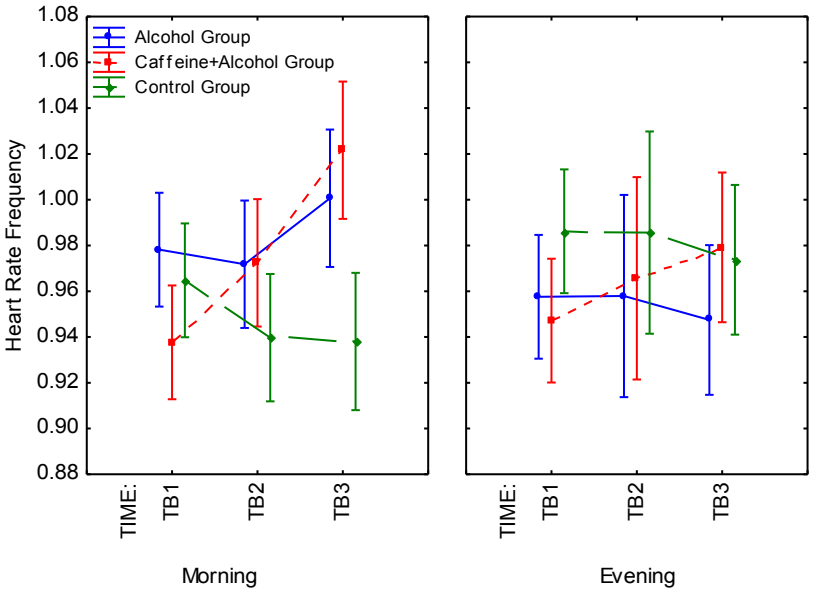

Figure 77: Relative heart rate frequency during a Fitt‟s task for morning and evening experimentation (*alcohol* vs. *control: F* (1, 68) = 5.49, p<0.03, *caffeine+alcohol* vs. *control: F* (1, 68) = 5.24, p<0.03). Vertical bars denote 95% confidence intervals.

Gender showed to have no effect on heart rate for the stimulus response task. Similarly, no interaction between gender and time of day was present in group comparisons.

Heart rate variability- RMSSD

TASK-RELATED EFFECTS

Heart rate variability for RMSSD was significantly lower in the *alcohol* group when compared to the *control* group (*F* (2, 134) = 4.08, p<0.02) and when compared to the *caffeine+alcohol* group (*F* (2, 134) = 4.78, p<0.01). Further, a significant change in heart rate variability was observed between the *caffeine+alcohol* and *control* groups (*F* (1, 68) = 3.99, p<0.05) - these results are displayed in Figure 81. The *alcohol* group showed the lowest variability in heart rate, indicating a higher cognitive workload, whereas the *control* group experienced the highest variability in RMSSD and hence the lowest cognitive workload.

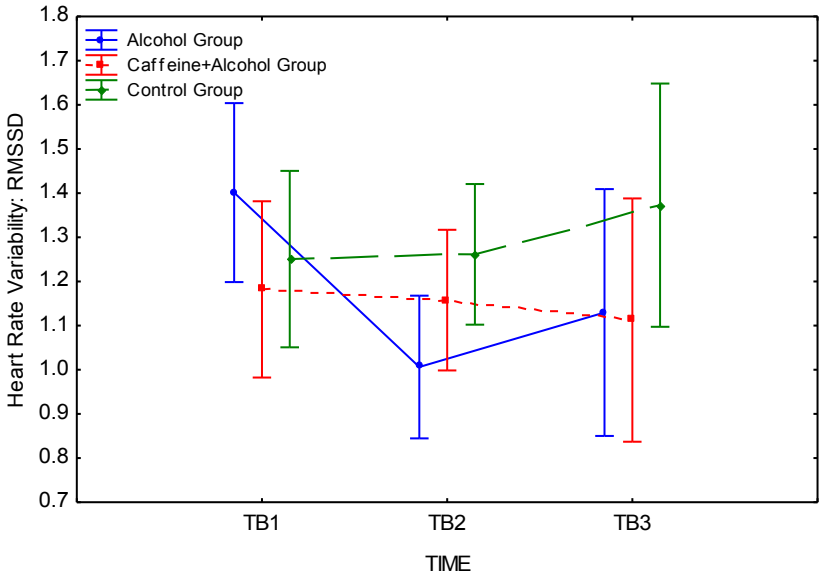

Figure 78: Relative heart rate variability (RMSSD) during a Fitt‟s task (*alcohol* vs. *control: F* (2, 134) = 4.08, p<0.02), *alcohol* vs. *caffeine+alcohol: F* (2, 134) = 4.78, p<0.01, *caffeine+alcohol* vs. *control: F* = (1, 68) = 3.99, p<0.05). Vertical bars denote 95% confidence intervals.

Heart rate variability- High Frequency Power

TASK-RELATED EFFECTS

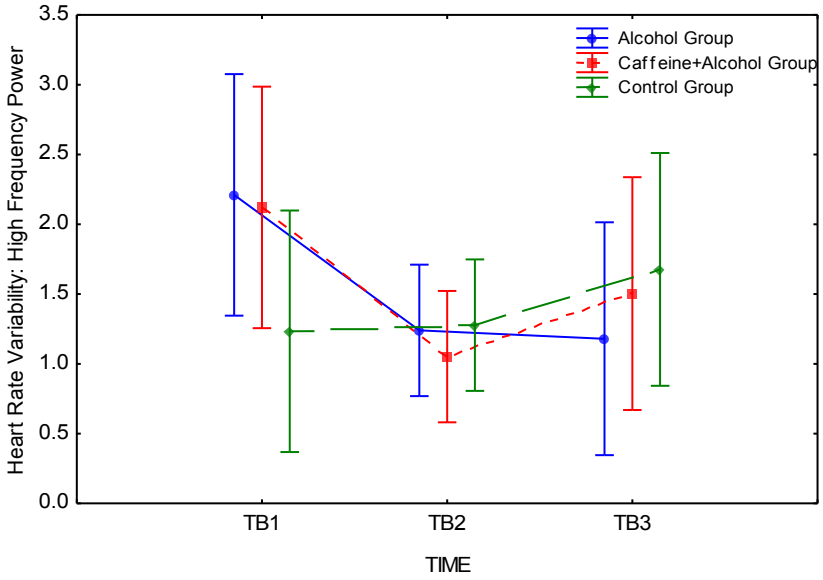

Figure 79: Relative heart rate variability (High Frequency Power) during a Fitt‟s task (*alcohol* vs. *control: F* (2, 136) = 4.79, p<0.01), *caffeine+alcohol* vs. *control: F* (2, 136) = 3.37, p<0.04). Vertical bars denote 95% confidence intervals.

Significant effects for High Frequency Power are found between the *alcohol* group and the *control* group (F (2, 136) = 4.79, p<0.01) and the *caffeine+alcohol* group when compared to the *control* group (F (2, 136) = 3.37, p<0.04 - see Figure 79). Alcohol consumption reduced High Frequency Power during TB2 for both experimental groups, the *caffeine+alcohol* group illustrating lower heart rate variability at that stage. Alcohol consumption significantly reduced the high frequency component of heart rate variability when compared to *control* participants.

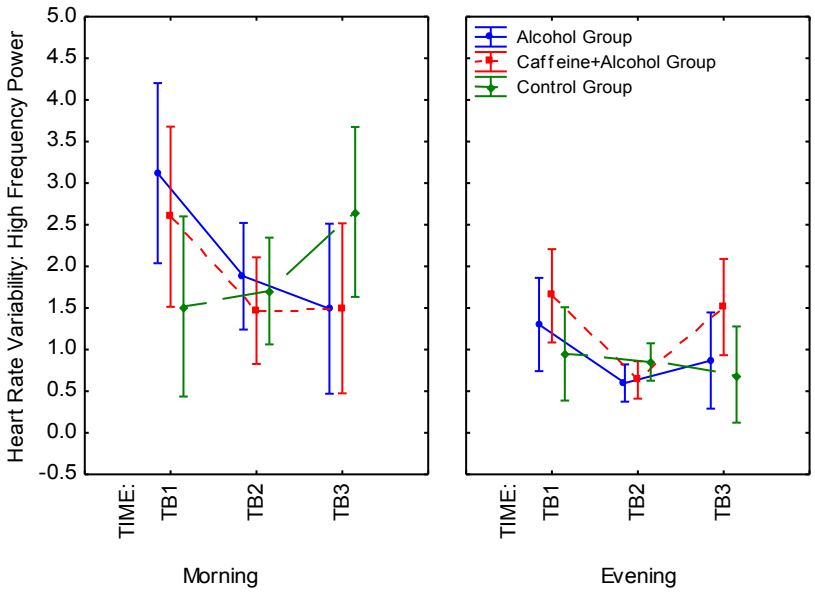

Figure 80: Relative heart rate variability (High Frequency Power) during a Fitt‟s task for morning and evening experimentation (*alcohol* vs. *control: F* (2, 136) = 3.66, p<0.03), *caffeine+alcohol* vs. *control: F* (2, 136) = 3.36, p<0.03). Vertical bars denote 95% confidence intervals.

Heart rate variability for the *alcohol* group was significantly different between morning and evening experimentation when compared to the *control* group (F (2, 136) = 3.66, p<0.03). Similarly, the difference between the *caffeine+alcohol* and *control* groups for the same result was also significant (F (2, 136) = 3.36, p<0.03); therefore the time of day at which alcohol consumption occurs has a significant impact on heart rate variability. As shown in Figure 80, High Frequency Power for heart rate variability was higher for experimentation in the morning. The introduction of alcohol resulted in a marked decrease in heart rate variability during TB2 for both morning and evening testing sessions.

Heart rate variability- Low Frequency Power

TASK-RELATED EFFECTS

Low Frequency Power analysis revealed statistically significant results between the *alcohol* and *control* groups (F (2, 136) = 3.16, p<0.05) as well as between the *alcohol* and *caffeine+alcohol* groups (F (2, 136) = 5.54, p<0.01). Figure 81 shows the *alcohol* group - post alcohol ingestion – recorded the lowest variability in the low frequency band of heart rate. The combination of caffeine and alcohol consumption imposed little difference in heart rate variability, as measured by Low Frequency Power.

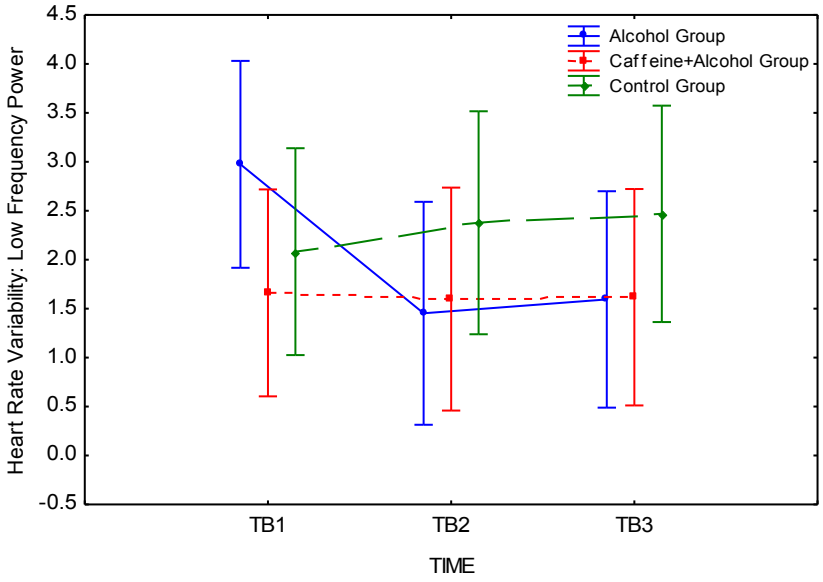

Figure 81: Relative heart rate variability (Low Frequency Power) during a Fitt‟s task (*alcohol* vs. *control: F* (2, 136) = 3.16, p<0.05, *alcohol* vs. *caffeine+alcohol: F* (2, 136) = 5.54, p<0.01). Vertical bars denote 95% confidence intervals.

The analysis of the effect of time of day on heart rate variability during response testing showed statistical significance between groups (Figure 82). Heart rate variability for the respective times of day was significantly different between the *alcohol* and *control* groups (F (1, 68) = 6.03, p<0.02). Alcohol consumption imposed a more pronounced effect on heart rate variability, demonstrating increased variability in heart rate during morning experimentation and the lowest variability during evening experimentation. Further, the *alcohol* group demonstrated a greater decrease in heart rate variability during TB2 than that experienced by the *caffeine+alcohol* group. Therefore, the consumption of caffeine seems to antagonise the effect of alcohol.

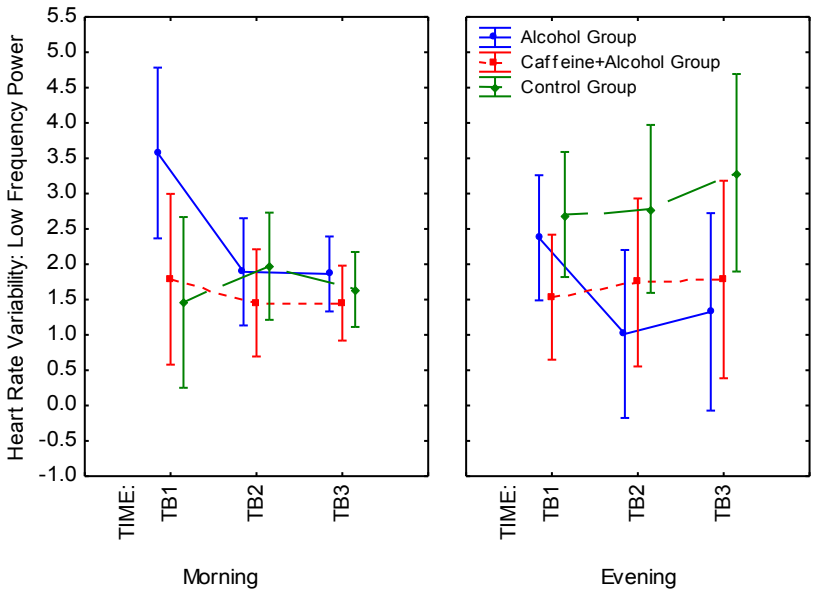

Figure 82: Relative heart rate variability (Low Frequency Power) during a Fitt"s task (*alcohol* vs. *control: F* (1, 68) = 6.03, p<0.02). Vertical bars denote 95% confidence intervals.

Body Temperature

TASK-RELATED EFFECTS

Skin temperature did not show any significant changes between all group comparisons, inclusive of time of day and gender effects.

Neural Reflex Task

Heart rate frequency

DIFFERENTIALLY-RELATED EFFECTS

Heart rate frequency showed similar trends across all groups. A significant effect for steering sensitivity-related heart rate was observed in the comparisons of *caffeine+alcohol* with the *alcohol* and *control* groups (*F* (1, 68) = 5.41, p<0.03) and (*F* (1, 68) = 6.07, p<0.02) respectively. The trend revealed by the *caffeine+alcohol* group is indicative of low sensitivity steering having a higher heart rate than high sensitivity. The opposite is observed in the *alcohol* and *control* groups, contributing to the significance observed between these comparisons (Figure 83). Therefore, caffeine consumption in combination with alcohol has a large impact on heart rate while driving under conditions of high and low steering sensitivity.

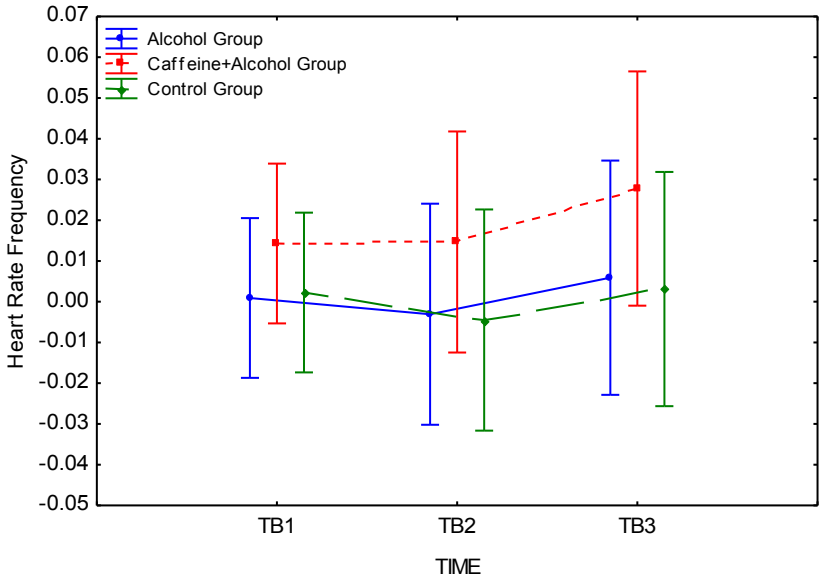

Figure 83: Relative effect of an increased proprioceptive feedback demand on heart rate frequency (*alcohol* vs. *caffeine+alcohol:* F (1, 68) = 5.41, $p<0.03$, *caffeine+alcohol* vs. *control:* F (1, 68) = 6.07, $p<0.02$). Vertical bars denote 95% confidence intervals.

A significant effect of heart rate between the *caffeine+alcohol* and *control* groups, as a factor of time of day was observed for high vs. low steering sensitivity (F (1, 68) = 11.51, $p<0.01$). The combination of caffeine and alcohol consumption had a significantly greater impact on heart rate as a function of steering complexity during morning experimentation, when compared to evening experimentation. The time of day at which the neural reflex task was performed appeared to have an impact on the heart rates of participants from the *alcohol* and *caffeine+alcohol* groups. This was further underpinned by the difference in heart rate for high and low sensitivity steering between the *alcohol* and. *control* groups (F (1, 68) = 3.98, $p<0.06$).

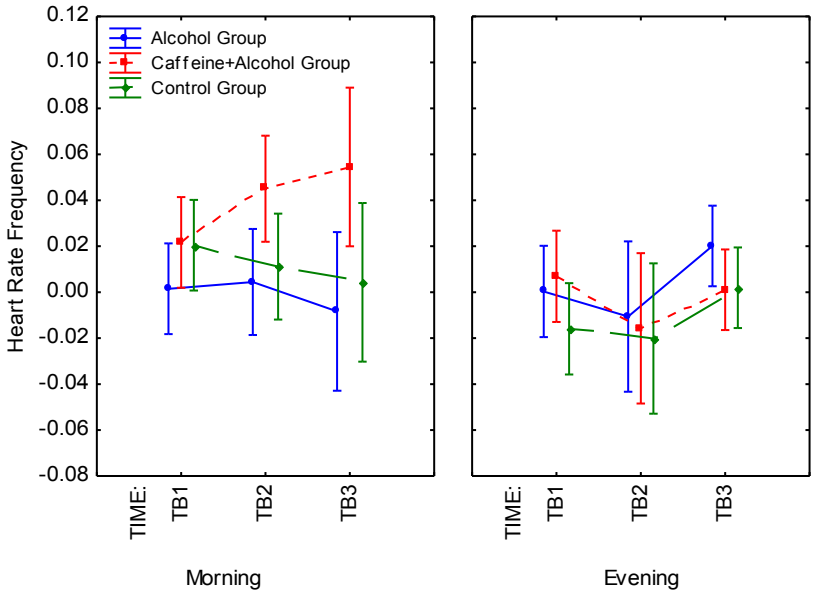

Figure 84: Relative effect of an increased proprioceptive feedback demand on heart rate frequency for morning and evening experimentation (*alcohol* vs. *caffeine+alcohol: F* (1, 68) = 11.51, p<0.01). Vertical bars denote 95% confidence intervals.

Comparisons for gender-related heart rate indicated a significant effect between the *alcohol* and *control* groups (*F* (2, 136) = 3.54, p<0.04), with alcohol consumption increasing heart rate between complexities. Gender related heart rate between high and low sensitivity driving indicated that female participants‟ from all groups incurred a higher heart rate when compared to male participants. Female *alcohol* group participants experienced a lower complexity- related heart rate indicative of a higher heart rate in the complex driving task. The male participants from these groups experienced increased differences in heart rate between high and low steering sensitivity, indicating heart rate to be higher in low steering sensitivity.

TASK-RELATED EFFECTS

Average heart rate for the tracking task showed the *caffeine+alcohol* group to have a significantly higher heart rate in comparison to both the *alcohol* and *control* groups, (*F* (2, 136) = 5.95, p<0.01) and (*F* (2, 136) = 20.80, p<0.01) respectively (Figure 85). The administration of alcohol resulted in an increased heart rate for the *caffeine+alcohol* group.

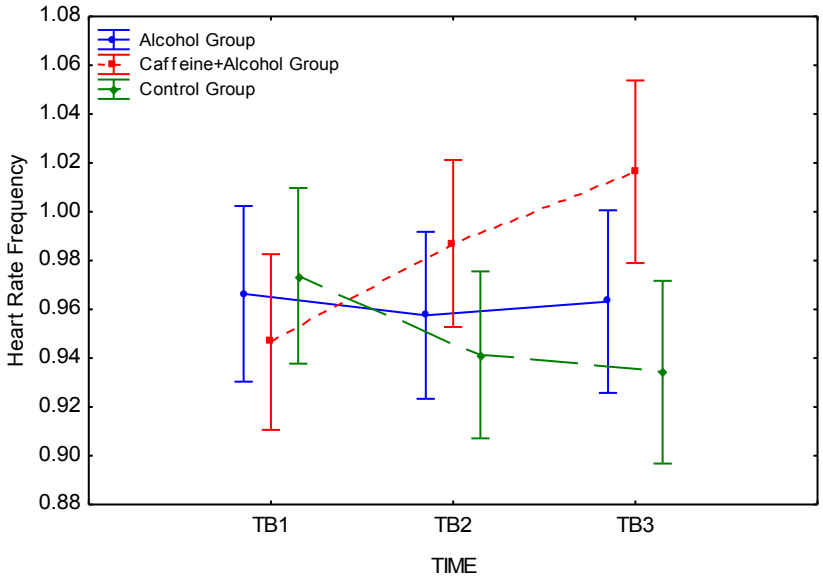

Figure 85: Relative heart rate frequency for a line tracking task (*alcohol* vs. *caffeine+alcohol: F* (2, 136) = 5.95, p<0.01) *caffeine+alcohol* vs. *control: F* (2, 136) = 20.80, p<0.01). Vertical bars denote 95% confidence intervals.

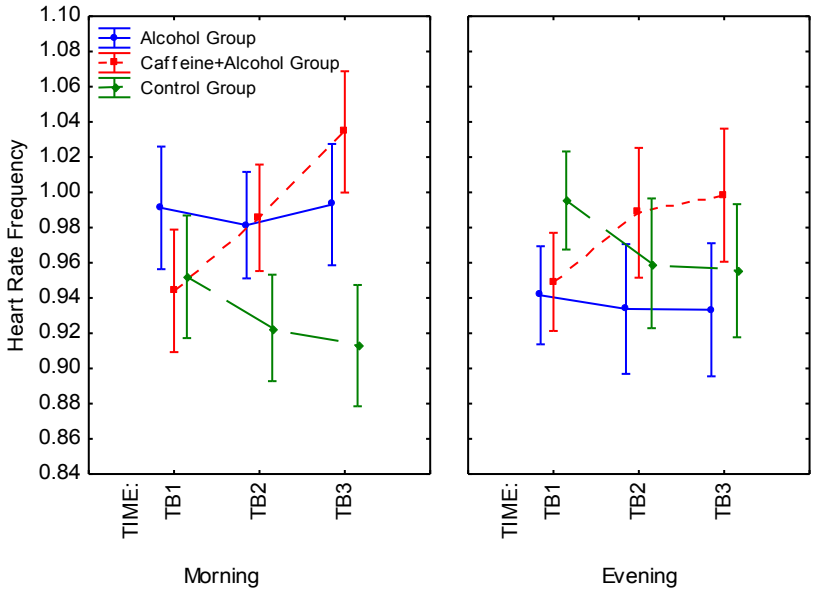

Figure 86: Relative heart rate frequency for a line tracking task for morning and evening experimentation (*alcohol* vs. *control: F* (1, 68) = 15.54 p<0.01, *caffeine+alcohol* vs. *control: F* (1, 68) = 5.36, p<0.03). Vertical bars denote 95% confidence intervals.

Morning alcohol consumption resulted in a significantly higher heart rate for the experimental groups when compared to the *control* group and to evening experimentation, *alcohol* vs. *control* (*F* (1, 68) = 15.54 p<0.01), and *caffeine+alcohol* vs. *control* (*F* (1, 68) =

5.36, p<0.03). Therefore, time of day elicited large changes in heart rate across all group comparisons, with morning experimentation resulting in a greater difference in heart rate between groups when compared to evening experimentation (Figure 86).

Heart rate variability- RMSSD

DIFFERENTIALLY-RELATED EFFECTS

No significant group differences were observed in heart rate variability for a change in task complexity.

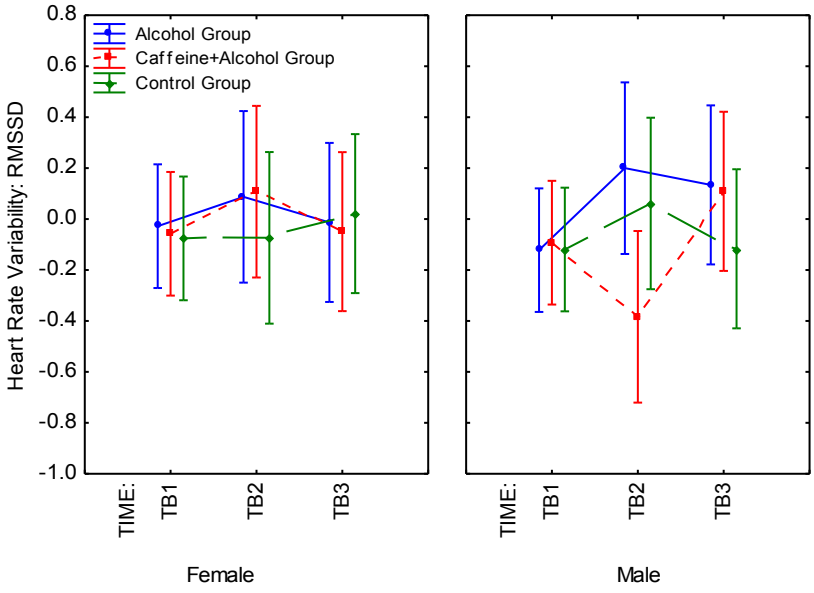

Figure 87: Relative effect of an increased proprioceptive feedback demand on heart rate variability for males and females (*caffeine+alcohol* vs. *control: F* (2, 136) = 3.78, p<0.03). Vertical bars denote 95% confidence intervals.

A significant gender effect was observed in heart rate variability in the *caffeine+alcohol* and *control* comparison (*F* (2, 136) = 3.78, p<0.03). Male *caffeine+alcohol* group participants showed an increased difference in heart rate variability between simple and complex steering sensitivity compared to the *alcohol* and *control* groups (Figure 87). This difference occurs immediately post- ingestion of alcohol. The difference in heart rate variability between high and low sensitivity between female participants was fairly similar throughout testing. Further, female heart rate variability depicted low sensitivity heart rate variability to be higher than high sensitivity heart rate variability. The introduction of alcohol increased complexity-related heart rate variability in males and females for both experimental groups (excluding males from the *caffeine+alcohol* group). Both sexes from

the two experimental groups experienced an increase in heart rate variability, suggestive of lower cognitive workload.

TASK-RELATED EFFECTS

As with the differential effects, task effects did not show significant group differences in heart rate variability. As depicted in Figure 88, a significant time of day effect for heart rate variability was observed between the *alcohol* and *control* groups (F (2, 136) = 3.66, p<0.03). The *alcohol* group showed a lower variability in heart rate than the *control* group in both morning and evening experimentation. This is suggestive of a higher cognitive workload in the *alcohol* group.

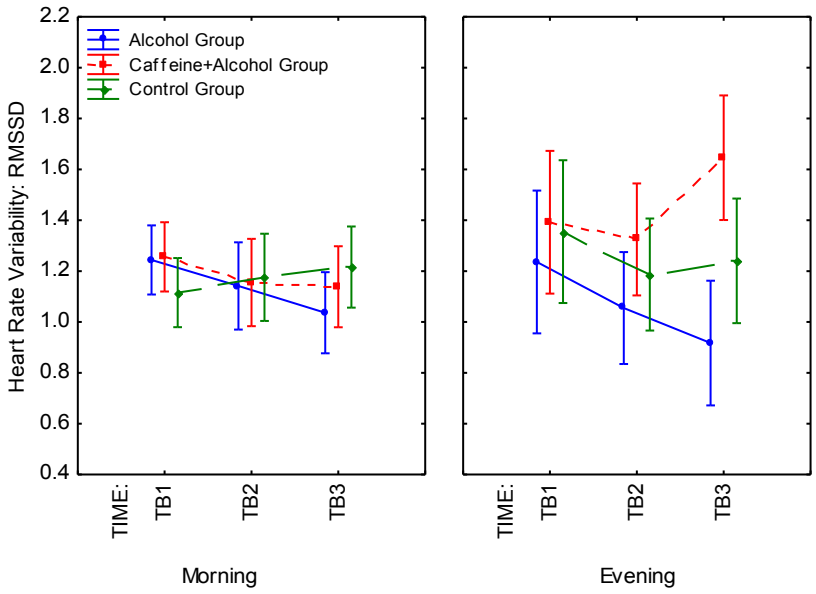

Figure 88: Relative heart rate variability for a line tracking task for morning and evening experimentation (*alcohol* vs. *control*: F (2, 136) = 3.66, p<0.03. *alcohol* vs. *caffeine+alcohol*: F (1, 68) = 6.45, p<0.02). Vertical bars denote 95% confidence intervals.

Furthermore, a significant effect between the *alcohol* and the *caffeine+alcohol* group indicated a higher heart rate variability demonstrated by the *caffeine+alcohol* group (F (1, 68) = 6.45, p<0.02). This indicates a lower cognitive workload experienced by the *caffeine+alcohol* group.

Gender imposed a significant effect in heart rate variability between the *alcohol* and *control* groups (F (2, 136) = 3.22, p<0.05). Female comparisons between these groups indicated significantly lower heart rate variability witnessed in the *alcohol* group throughout test

batteries whereas the male comparison showed the *alcohol* group experiencing higher variability in heart rate post- alcohol ingestion

Body Temperature

DIFFERENTIALLY-RELATED EFFECTS

Alcohol consumption in a driving simulation neural reflex task did not impose any significant changes in skin temperature with task complexity.

TASK-RELATED EFFECTS

Skin temperature does not appear to be sensitive for the impact of alcohol nor for the combined consumption of caffeine and alcohol. A significant effect on skin temperature was demonstrated between the *alcohol* and *control* groups (F (2, 136) = 3.54, $p<0.04$) depending on gender, with male *alcohol* participants incurring significantly higher skin temperature values post- alcohol ingestion (Figure 89).

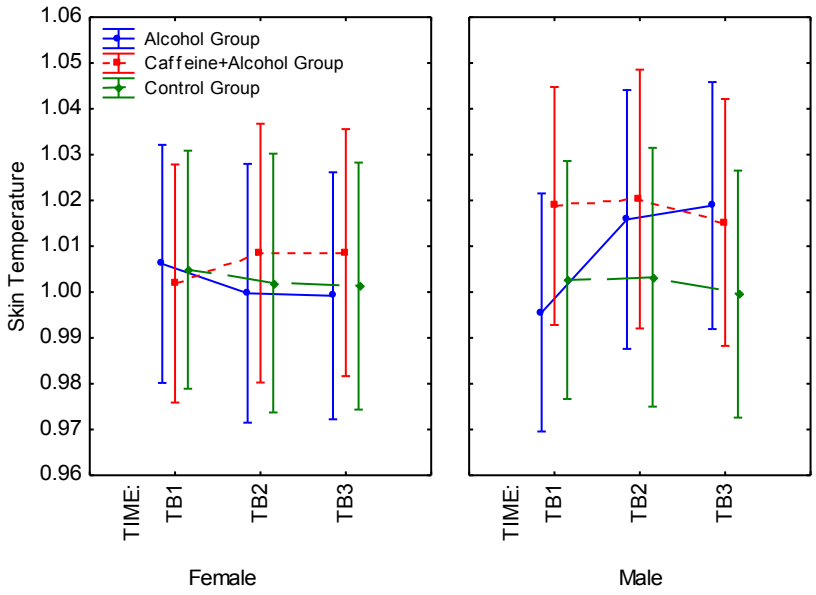

Figure 89: Relative skin temperature for a line tracking task indicating gender-related differences (*alcohol* vs. *control:* F (2, 136) = 3.54, $p<0.04$). Vertical bars denote 95% confidence intervals.

Summary of physiological results

Table XIII: Differential heart rate results.

DIFFERENTIAL PERFORMANCE			Alcohol vs Control				Alcohol vs Caffeine				Caffeine vs Control			
Dependent Test	Variable	Factor	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening
Accommod-ation	HRF	S vs C	ALC ↑ p<0.03	-	-	□ p<0.10	-	-	-	-	-	-	-	□ p<0.07
Visual Detection	HRF	S vs C	-	-	-	-	-	-	-	□ p<0.02 *	-	-	-	-
Reading	HRF	S vs C	-	-	-	-	ALC ↓p<0.07	-	-	□ p<0.09	-	-	-	-
Memory	HRF	S vs C	ALC ↑ p<0.01 *	-	ALC ↑M p<0.10	-	-	-	-	-	CAF ↑ p<0.01 *	-	CAF ↑ M ↓ E p<0.03	-
		60/90	ALC ↑ p<0.09	-	ALC ↑ p<0.09	-	ALC ↓ ST ↑ LT p<0.03	-	-	□ p<0.07	CAF ↑ ST ↓ LT p<0.01	-	-	-
		SC*60/90	-	-	ALC ↑ p<0.03	-	-	-	-	-	-	-	CAF ↑ M ↓ E p<0.02	-
Driving Simulator	HRF	S vs C	-	ALC ♂↑ ♀↓ p<0.04	ALC ↑M ↓ E p<0.06 *	-	ALC ↓ p<0.03 *	-	ALC ↓ p<0.01 *	□ p<0.05 *	CAF ↑ p<0.01 *	-	-	□ p<0.06 *

ALC = alcohol group CAF = caffeine group ↑ = Increase/ Higher ↓ = Decreased/ Lower ♀ = Female ♂ = Male M = Morning E = Evening ST = Short term memory LT = Long term memory □ = Interaction effect * = Effect without time Alcohol = Significant difference p<0.05 (-) = p<0.20

Table XIV: Task-related heart rate results.

TASK EFFECTS		Alcohol vs Control				Alcohol vs Caffeine				Caffeine vs Control			
Dependent Test	Variable	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening
Accommod-ation	HRF	-	-	-	□ p<0.10	-	-	-	-	CAF ↑ p<0.01	-	-	□ p<0.09
Visual Detection	HRF	-	-	-	-	ALC ↓ p<0.07	-	-	□ p<0.02	CAF ↓ p<0.01	-	-	-
Reading	HRF	ALC ↑ p<0.02	-	-	□ p<0.04	-	-	-	□ p<0.04	CAF ↑ p<0.01	-	-	-
Memory	HRF	ALC ↑ p<0.09	-	-	□ p<0.07	ALC ↓ p<0.09	-	-	-	CAF ↑ p<0.01	-	CAF ↑M ↓E p<0.10	-
Stimulus Response	HRF	-	-	ALC ↑M ↓E p<0.03 *	-	ALC ↓ p<0.01	-	-	-	CAF ↑ p<0.01	-	CAF ↑M p<0.03 * CAF ↑M p<0.09	-
Driving Simulator	HRF	-	-	ALC ↑ p<0.01 *	-	ALC ↓ p<0.01	-	ALC ↓ p<0.10	-	CAF ↑ p<0.01	-	CAF ↑ M p<0.03 *	-

ALC = alcohol group CAF = caffeine group ↑ = Increase/ Higher ↓ = Decreased/ Lower ♀ = Female ♂ = Male M = Morning E = Evening □ = Interaction effect * = Effect without time Alcohol = Significant difference p<0.05 (-) = p<0.20

Table XV: Differential heart rate variability effects.

DIFFERENTIAL PERFORMANCE			Alcohol vs Control				Alcohol vs Caffeine				Caffeine vs Control			
Dependent Test	Variable	Factor	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening
Accommod-ation	rMSSD	S vs C	-	-	-	-	-	-	-	-	CAF ↑ p<0.08 *	-	CAF ↑ p<0.07 *	□ p<0.09
	HF Power	S vs C	ALC ↑ p<0.10	ALC ↑ p<0.10 *	-	□ p<0.07	-	ALC ♂ ↑ ♀ ↓ p<0.05	-	-	CAF ↓ p<0.09	CAF ↓ p<0.01 *	-	-
	LF Power	S vs C	-	-	-	□ p<0.05	-	-	-	-	-	-	CAF ↑ M p<0.01	
Visual Detection	rMSSD	S vs C	-	ALC ↑ p<0.03	-	-	-	-	CAF ↑ p<0.10 *	-	-	-	CAF ↑M p<0.02 * CAF ↑ p<0.06	-
	HF Power	S vs C	-	-	-	-	-	-	-	-	-	-	-	-
	LF Power	S vs C	-	-	-	-	-	-	-	-	-	-	CAF ↑ M p<0.10	-
Reading	rMSSD	S vs C	-	ALC ↑ p<0.05 *	-	-	-	ALC ♀↑ p<0.02 *	ALC ↑M p<0.07 *	-	-	-	CAF ↑ p<0.08 *	-
	HF Power	S vs C	-	-	-	-	-	-	-	-	-	-	-	-
	LF Power	S vs C	-	-	-	-	-	-	-	-	-	-	-	-
Memory	rMSSD	S vs C	-	ALC ♂↑p<0.06	-	-	-	-	-	□ p<0.10	-	-	-	□ p<0.08
		60/90	ALC ↓ p<0.05	-	-	-	-	-	-	-	CAF ↑ p<0.01	-	-	-
		SC*60/90	-	-	-	-	ALC ↑ p<0.05 * ALC ↑ p<0.07	-	-	-	-	-	□ p<0.09	-
	HF Power	S vs C	-	-	-	-	-	ALC ↓ p<0.06 *	-	-	-	-	-	-
		60/90	-	-	-	-	-	-	-	-	CAF ↑ p<0.05	-	-	-
		SC*60/90	ALC ↑ p<0.07	-	-	-	-	-	-	-	CAF ↑ p<0.05	-	-	-
	LF Power	S vs C	-	-	-	-	ALC ↑ p<0.09 *	-	-	□ p<0.03	CAF ↓ p<0.10 *	-	-	□ p<0.05
		60/90	-	-	-	□ p<0.07	-	-	-	-	-	-	-	□ p<0.08
		SC*60/90	-	-	-	-	ALC ↑ p<0.10	-	-	-	-	-	-	-
Driving Simulator	rMSSD	S vs C	-	-	-	-	-	-	ALC ↓p<0.06	-	-	CAF ♀↓ p<0.03	-	□ p<0.08
	HF Power	S vs C	-	ALC ↓ p<0.02 *	ALC ↓ p<0.07 *	-	ALC ↓ p<0.04 *	ALC ↓ p<0.09 *	ALC ↓ p<0.03	□ p<0.06	-	-	-	□ p<0.05
	LF Power	S vs C	-	-	ALC ↓ p<0.04 *	-	-	-	-	-	-	-	-	-

ALC = alcohol group CAF = caffeine group ↑ = Increase/ Higher ↓ = Decreased/ Lower ♀ = Female ♂ = Male M = Morning E = Evening □ = Interaction effect * = Effect without time Alcohol = Significant difference p<0.05 (-) = p<0.20

Table XVI: Task-related heart rate variability effects.

TASK EFFECTS		Alcohol vs Control				Alcohol vs Caffeine				Caffeine vs Control			
Dependent Test	Variable	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening
Accommod-ation	rMSSD	-	-	-	-	-	-	-	-	CAF ↑ p<0.01	-	-	-
	HF Power	ALC ↑ p<0.09 *	-	-	-	-	-	-	-	CAF ↑ p<0.09 *	-	-	-
	LF Power	-	-	-	-	-	-	-	-	-	-	-	-
Visual Detection	rMSSD	-	ALC ↑ p<0.06	ALC ↑ M p<0.07	-	-	-	-	-	-	-	-	-
	HF Power	-	-	-	-	-	-	-	-	-	-	-	-
	LF Power	-	-	ALC ↓ p<0.10	-	-	-	-	-	-	-	-	-
Reading	rMSSD	-	-	-	-	-	-	ALC ↓M p<0.05	-	CAF ↑M p<0.01	-	-	-
	HF Power	-	-	-	-	ALC ↓ p<0.07	-	-	-	-	-	-	-
	LF Power	-	-	-	ALC ↑ p<0.09	-	-	-	-	-	CAF ↑ p<0.08	-	-
Memory	rMSSD	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-
	HF Power 60-90	-	-	-	-	-	-	-	-	-	-	-	-
		-	ALC ♂ ↑ p<0.04	-	-	ALC ↓ p<0.07	-	-	-	-	-	-	-
	LF Power 60-90	-	-	-	-	-	-	-	-	-	-	-	-
		ALC ↑ST p<0.04 *	-	-	-	-	-	ALC ↑ p<0.09 *	-	-	-	-	-
Stimulus Response	rMSSD 60-90	ALC ↓ p<0.02	-	ALC ↓ p<0.10 *	□ p<0.05	ALC ↑ p<0.01	-	-	□ p<0.07	CAF ↑ p<0.05 *	-	-	-
	HF Power	ALC ↓ p<0.01	-	ALC ↓ M p<0.03	-	-	-	-	-	CAF ↓p<0.04	-	CAF ↓ M p<0.03	-
	LF Power	ALC ↓ p<0.05	-	ALC ↑ M p<0.02 *	-	ALC ↓ p<0.01	-	-	□ p<0.07	-	-	CAF ↓ p<0.09	□ p<0.05
Driving Simulator	rMSSD	-	ALC ↓ p<0.05	ALC ↓ p<0.03	-	-	-	ALC ↓ p<0.02 *	-	-	-	-	□ p<0.08
	HF Power	-	ALC ↓ p<0.07	ALC ↓ p<0.04	-	-	-	ALC ↓ p<0.07 *	-	-	-	CAF ↑ p<0.10	-
	LF Power	-	ALC ↓ p<0.04	-	-	ALC ↓ p<0.05	-	-	-	-	-	CAF ↑ p<0.10	-

ALC = alcohol group CAF = caffeine group ↑ = Increase/ Higher ↓ = Decreased/ Lower ♀ = Female ♂ = Male M = Morning E = Evening □ = Interaction effect * = Effect without time Alcohol = Significant difference p<0.05 (-) = p<0.20

Table XVII: Differential skin temperature results.

DIFFERENTIAL PERFORMANCE			Alcohol vs Control				Alcohol vs Caffeine				Caffeine vs Control			
Dependent Test	Variable	Factor	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening
Accommod-ation	Skin Temperature	S vs C	-	-	-	-	ALC ↑ p<0.06	-	-	-	-	-	-	-
Visual Detection	Skin Temperature	S vs C	-	-	-	-	ALC ↑ p<0.03	-	-	-	-	-	-	□ p<0.10
Reading	Skin Temperature	S vs C	-	-	-	-	-	-	-	-	CAF ↑ p<0.10	-	-	-
Memory	Skin Temperature	S vs C	ALC ↓ p<0.04	-	-	-	-	-	-	-	-	-	-	-
		60/90	-	□ p<0.09	-	-	-	ALC ♂↓ p<0.03	-	-	-	-	-	-
		SC*60/90	-	-	-	-	-	-	-	-	-	-	-	-
Fitts	Skin Temperature	S vs C	-	-	-	-	-	-	-	-	-	-	-	-
Driving	Skin Temperature	S vs C	-	-	-	□ p<0.03	-	ALC ↓ p<0.07	ALC ↓ p<0.10	-	-	-	-	-

ALC = alcohol group CAF = caffeine group ↑ = Increase/ Higher ↓ = Decreased/ Lower ♀ = Female ♂ = Male M = Morning E = Evening □ = Interaction effect * = Effect without time Alcohol = Significant difference p<0.05 (-) = p<0.20

Table XVIII: Task-related skin temperature results.

TASK EFFECTS		Alcohol vs Control				Alcohol vs Caffeine				Caffeine vs Control			
Dependent Test	Variable	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening
Accommod-ation	Skin Temperature	-	-	ALC ↓ p<0.03	-	-	-	-	-	-	-	-	-
Visual Detection	Skin Temperature	-	-	ALC ↓ p<0.01	ALC ↓ p<0.03	-	-	ALC ↑E p<0.03	-	-	CAF ↓ p<0.07	-	-
Reading	Skin Temperature	-	ALC ↓ p<0.08	-	-	-	ALC ↑ p<0.05	-	-	-	-	-	-
Memory	Skin Temperature	-	ALC ↓ p<0.10	-	-	-	-	-	-	-	-	-	-
	60-90	-	-	ALC ↓ p<0.01 *	-	-	-	-	-	-	-	CAF ↑ p<0.09 *	□ p<0.09
Fitts	Skin Temperature	-	-	-	-	-	-	-	-	-	-	-	-
Driving	Skin Temperature	-	-	-	-	-	ALC ♀↓ p<0.04	-	-	-	-	-	-

ALC = alcohol group CAF = caffeine group ↑ = Increase/ Higher ↓ = Decreased/ Lower ♀ = Female ♂ = Male M = Morning E = Evening □ = Interaction effect * = Effect without time Alcohol = Significant difference p<0.05 (-) = p<0.20

OCULOMOTOR PARAMETERS

Oculomotor variables were measured to establish the effects of alcohol and *caffeine+alcohol* in visual and cognitive parameters. The *dikablis* eye-tracking system was utilised to measure the following variables: pupil diameter, saccade speed, saccade amplitude and fixation duration.

Visual Perceptual Performance

Accommodation Task

Pupil diameter

DIFFERENTIALLY-RELATED EFFECTS

Alcohol consumption and the combination of alcohol and caffeine consumption did not cause any significant changes in pupil diameter during the accommodation task.

TASK-RELATED EFFECTS

No significant differences were observed for the average changes in pupil size for the accommodation task.

Saccade Speed

DIFFERENTIALLY-RELATED EFFECTS

No significant differences in saccade speed were observed between the three groups tested during the accommodation task.

TASK-RELATED EFFECTS

Average saccade speed showed no significant changes over time for the accommodation task. Therefore alcohol had no effect on saccade speed while performing an accommodation task.

Saccade Amplitude

DIFFERENTIALLY-RELATED EFFECTS

Saccade amplitude did not show significant changes under the influence of alcohol and the combination of *caffeine+alcohol* for the accommodation task.

TASK-RELATED EFFECTS

No effects of group, time of day, gender or an interaction of these factors were present in analysis of saccade amplitude for the accommodation task.

Fixation Duration

DIFFERENTIALLY-RELATED EFFECTS

Fixation duration indicates a significant effect for gender-related accommodation between the *alcohol* and *caffeine+alcohol* groups (F (2, 136) = 3.11, $p<0.05$). As depicted in Figure 90 morning experimentation showed a smaller difference between the *alcohol* and *caffeine+alcohol* groups when compared to evening experimentation. The consumption of alcohol in both experimental groups resulted in an increased difference in fixation duration between static and dynamic accommodation. The *caffeine+alcohol* group incurred longer fixation durations in dynamic accommodation and the *alcohol* group showed longer fixation duration during static accommodation.

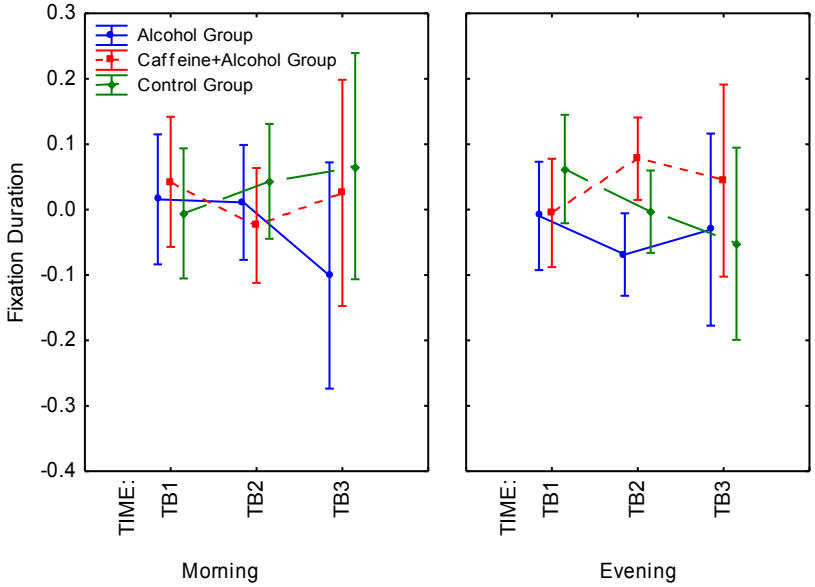

Figure 90: Relative effect of visual accommodation on fixation duration for morning and evening experimentation (*alcohol* vs. *caffeine+alcohol: F* (2, 136) = 3.11, $p<0.05$). Vertical bars denote 95% confidence intervals.

TASK-RELATED EFFECTS

No significant effects were observed across all group comparisons for task-related fixation duration.

Visual Detection Task

Pupil diameter

DIFFERENTIALLY-RELATED EFFECTS

Task complexity imposed no significant group differences in pupil diameter between static and dynamic accommodation.

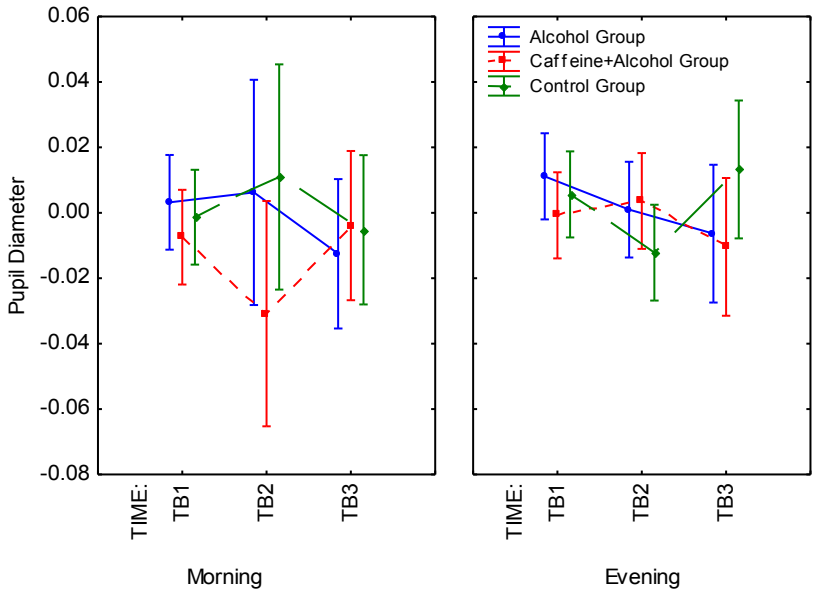

Figure 91: Relative effect of an increased information density during a visual detection task on pupil diameter for morning and evening experimentation (*caffeine+alcohol* vs. *control:* F (2, 136) = 3.21, $p<0.05$). Vertical bars denote 95% confidence intervals.

A significant difference in complexity-related pupil diameter was demonstrated between the *caffeine+alcohol* and *control* groups (F (2, 136) = 3.21, $p<0.05$). Post alcohol consumption, the *caffeine+alcohol* group experienced a significantly larger difference in pupil diameter between simple and complex visual detection, demonstrating increased pupil diameter during simple visual detection. Evening performance for the *caffeine+alcohol* group displayed the opposite trend to that observed during morning experimentation.

TASK-RELATED EFFECTS

Pupil diameter was significantly different between the *alcohol* and *caffeine+alcohol* groups for males and females (F (1, 68) = 3.63, p<0.03). As evidenced in (Figure 92) female pupil diameter was lower than males‟ when considering the *alcohol* group, with the inverse found for the *caffeine+alcohol* group. Alcohol consumption resulted in an increased pupil size for female *alcohol* group participants during TB2, and a decreased pupil size for males. Conversely *caffeine+alcohol* participants experienced a decrease in pupil size for females and an increase for males during TB2.

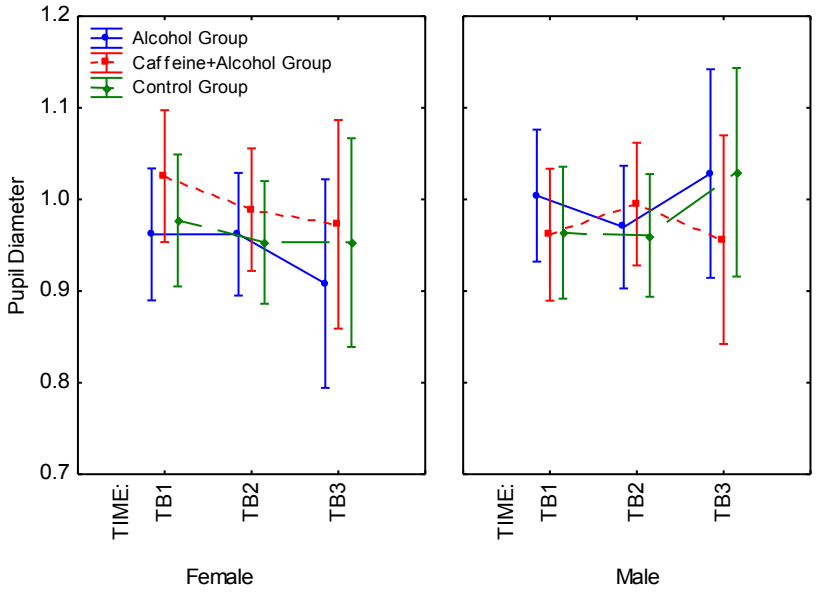

Figure 92: Relative pupil size during a visual detection reaction task for males and females (*alcohol* vs. *caffeine+alcohol: F* (1, 68) = 3.63, p<0.03). Vertical bars denote 95% confidence intervals.

Saccade Speed

DIFFERENTIALLY-RELATED EFFECTS

Saccade speed did not prove sensitive to a change in complexity.

TASK-RELATED EFFECTS

No significant task effects were demonstrated through statistical analysis of saccade speed as a function of group.

Saccade Amplitude

DIFFERENTIALLY-RELATED EFFECTS

This variable did not produce significant differences between groups.

TASK-RELATED EFFECTS

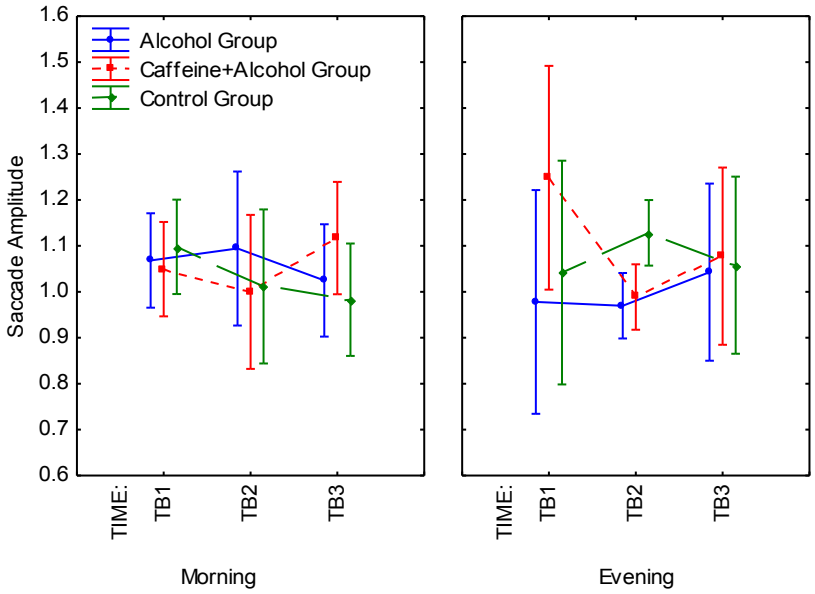

Figure 93: Relative saccade amplitude during a visual detection reaction task for morning and evening experimentation (*caffeine+alcohol* vs. *control: F* (2, 136) = 3.53, p<0.05). Vertical bars denote 95% confidence intervals.

Statistical analysis revealed a significant difference for time of day between the *caffeine+alcohol* and *control* groups (*F* (2, 136) = 3.53, p<0.05). As illustrated in Figure 93, morning experimentation affected saccade amplitude to a lesser degree for the *caffeine+alcohol* group than that observed in evening experimentation. Interpretation of evening saccade amplitude for the *caffeine+alcohol* group illustrated large amplitude during TB1. This amplitude decreased immediately after alcohol was consumed, thereafter increasing on the declining phase of the alcohol intoxication. Further, saccade amplitude was relatively consistent across all groups during morning experimentation.

Fixation Duration

DIFFERENTIALLY-RELATED EFFECTS

No significant differences were observed across all analyses and comparisons for the fixation duration during the visual detection task.

TASK-RELATED EFFECTS

Alcohol consumption and the combination of alcohol and caffeine consumption did not cause any significant changes in fixation duration during visual detection task performance.

Reading Task

Pupil diameter

DIFFERENTIALLY-RELATED EFFECTS

Comparisons between the *alcohol* and *control* groups and between the *alcohol* and *caffeine+alcohol* groups revealed two significant main effects for time of day, (F (1, 66) = 2.43, p<0.04) and (F (1, 64) = 4.51, p<0.02) respectively.

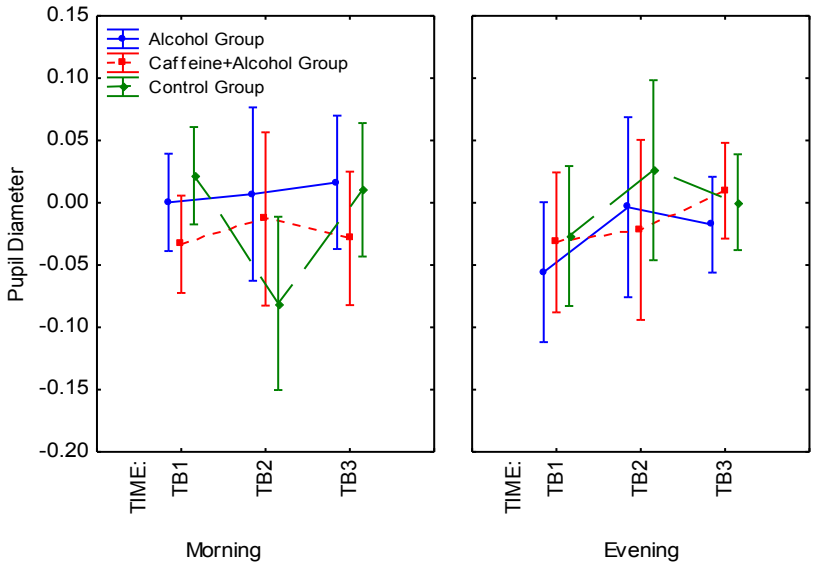

Figure 94: Relative effect of an increased visual pattern recognition difficulty on pupil diameter for morning and evening experimentation (*alcohol* vs. *control: F* (1, 66) = 2.43, p<0.04), *alcohol* vs. *caffeine+alcohol* (*F* (1, 64) = 4.51, p<0.02). Vertical bars denote 95% confidence intervals.

Within these comparisons (Figure 94), it is observed that the difference in pupil sizes between the *alcohol* and *control* group was far larger in morning experimentation. Further, within the *alcohol* group, the change in pupil size between test batteries in both experimental sessions was more constant than that witnessed within the *control* group. The *caffeine+alcohol* group, in comparison to the *alcohol* group, demonstrated a larger difference in pupil size during morning experimentation and a smaller difference in evening experimentation. Pupil diameter in the *alcohol* group was larger for low resolution reading in morning and smaller in low resolution during evening experimentation. Conversely, the *caffeine+alcohol* group presented an increasing trend for both morning and evening experimentation. The ingestion of alcohol, as seen in TB2, increased pupil diameter in both experimental groups.

TASK-RELATED EFFECTS

No significant effects were present in pupil diameter in comparisons between the *control* and experimental groups.

Saccade Speed

DIFFERENTIALLY-RELATED EFFECTS

A substantial group difference in saccade speed was demonstrated between high and low resolution reading within the *alcohol* vs. *control* comparison (F = (2, 126), $p<0.06$). Here, it is demonstrated that alcohol consumption had a substantial but non-significant effect on saccade speed while reading. Furthermore, two significant time of day effects were shown in the comparison between *alcohol* vs. *control* groups (F (1, 63) = 5.69, $p<0.02$), and the *caffeine+alcohol* vs. *control* comparison (F (1, 63) = 4.17, $p<0.05$: see Figure 95). Alcohol ingestion caused an increase in saccade speed for high and low resolution reading in both morning and evening experimental sessions. Alcohol consumption in the morning experimental sessions saw a higher saccade speed during low resolution reading during TB2. The *alcohol* group when compared to the *control* group demonstrated a reduced saccade speed for low resolution reading during TB3. The result in evening experimentation was similar; however the degree of speed reduction was larger- indicating significantly reduced saccade speed post- alcohol ingestion.

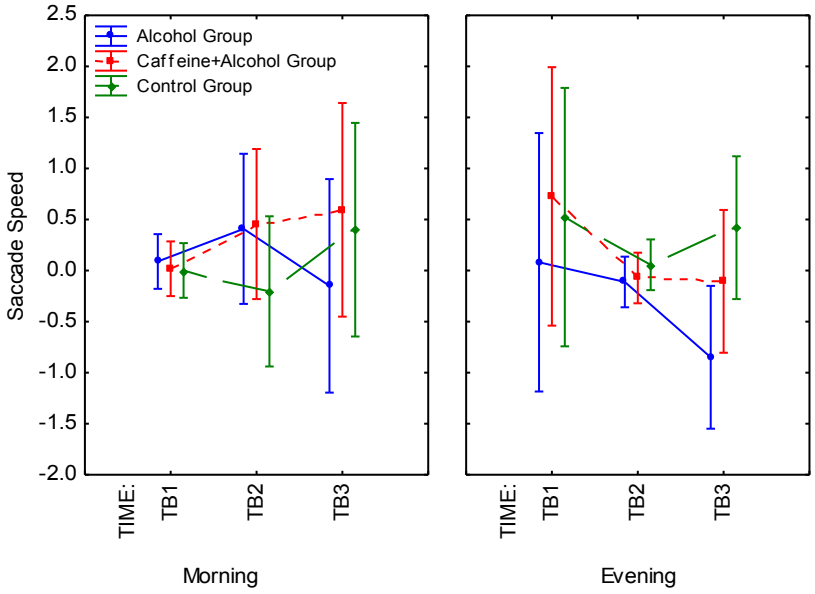

Figure 95: Relative effect of an increased visual pattern recognition difficulty on saccade speed for morning and evening experimentation (*alcohol* vs. *control: F* (1, 63) = 5.69, p<0.02), *caffeine+alcohol* vs. *control:* (*F* (1, 63) = 4.17, p<0.05). Vertical bars denote 95% confidence intervals.

The *caffeine+alcohol* group demonstrated a similar relationship to that of the *alcohol* group, however it denoted faster saccade speed for complex reading during TB3 in morning and evening experimentation when compared to the *alcohol* group. This suggests that caffeine inhibits the deterioration in saccade speed as experienced by the *alcohol* group in TB3.

TASK-RELATED EFFECTS

No significant effects for saccade speed were demonstrated for time of day, gender or any interaction effects across all group comparisons.

Saccade Amplitude

DIFFERENTIALLY-RELATED EFFECTS

Saccade amplitude indicated increased sensitivity to the time of day in which testing occurred, demonstrating a significant difference between *alcohol* and the *control* group (*F* (1, 63) = 6.18, p<0.02) and between the *caffeine+alcohol* and. the *control* group (*F* (1, 63) = 7.23, p<0.01).

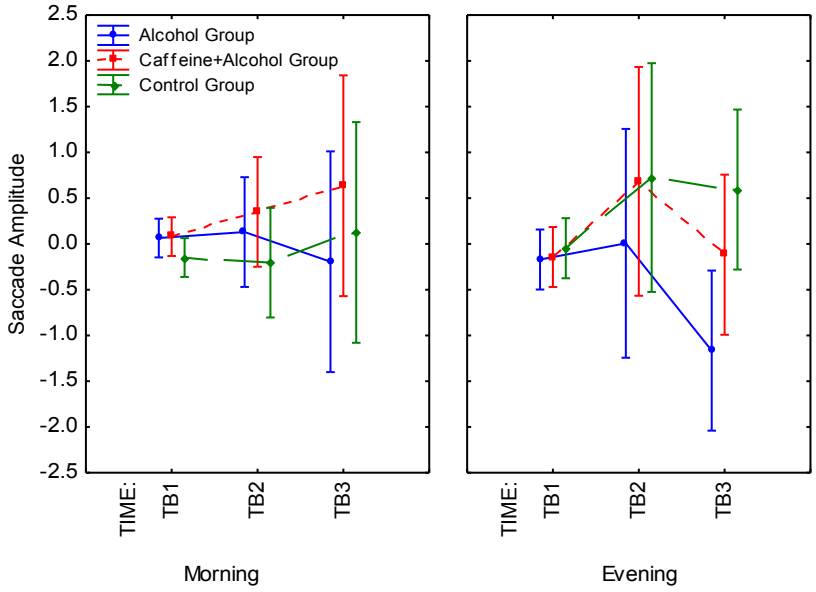

Figure 96: Relative effect of an increased visual pattern recognition difficulty on saccade amplitude for morning and evening experimentation (*alcohol* vs. *control: F* (1, 63) = 6.18, p<0.02, *caffeine+alcohol* vs. the *control:* (*F* = (1, 63) = 7.23, p<0.01). Vertical bars denote 95% confidence intervals.

As seen in Figure 96, evening performance showed a substantially different trend between the *alcohol* and *control* groups in comparing morning experimentation. Evening experimentation resulted in significantly reduced saccade amplitude after alcohol had been consumed – this degree of reduction was not seen in morning experimentation. Initially, post-alcohol consumption, a marginal increase in complexity-related saccade amplitude was witnessed in both the experimental groups. However, approximately 70 minutes after alcohol ingestion, the difference in saccade amplitude between high and low resolution during evening experimentation was at its lowest – indicating decreased amplitude during low resolution reading. Saccade amplitude in the *caffeine+alcohol* group during morning experimentation exemplified larger amplitude for complex reading, this being significantly different to the *control* group, which displayed relatively even saccade amplitude between complexities.

TASK-RELATED EFFECTS

No significant findings were observed for saccade amplitude in task-related performance.

Fixation Duration

DIFFERENTIALLY-RELATED EFFECTS

Fixation duration manifested no significant findings across group comparisons, inclusive of effects for time of day and gender.

TASK-RELATED EFFECTS

No significant findings were observed for fixation duration in task-related performance.

Memory Performance

Memory Recall Task

Pupil diameter

DIFFERENTIALLY-RELATED EFFECTS

Pupil diameter did not reflect significant effects across all group comparisons.

TASK-RELATED EFFECTS

No significant effects were presented for pupil diameter in task-related differences for memory recall.

Saccade Speed

DIFFERENTIALLY-RELATED EFFECTS

Saccade speed between simple and complex memory recall did not demonstrate any significant differences across all group comparisons. However, a substantial difference in saccade speed was present between simple and complex memory recall in the *alcohol* vs. *control* comparison (F (2, 134) = 2.90, $p<0.06$). As depicted in Figure 97, alcohol consumption creates a greater difference in saccade speed between simple and complex memory recall. In this example it is seen that the *alcohol* group elicited higher saccade speeds during complex memory recall- as evidenced by the positive difference between simple and complex recall. The difference in speeds between the *alcohol* and *control* groups reflects a substantial difference in oculomotor functioning, illustrating how alcohol impairs this oculomotor function.

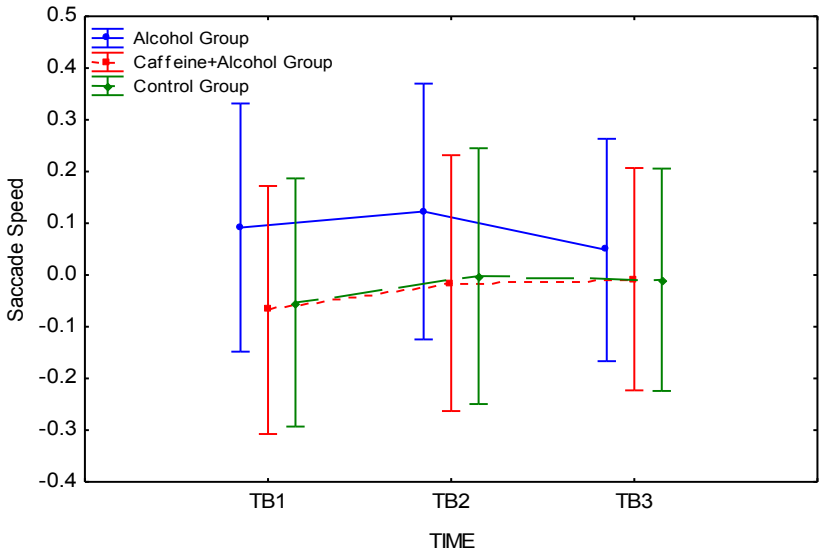

Figure 97: Relative effect of an increased memory capacity demand on saccade speed. Vertical bars denote 95% confidence intervals.

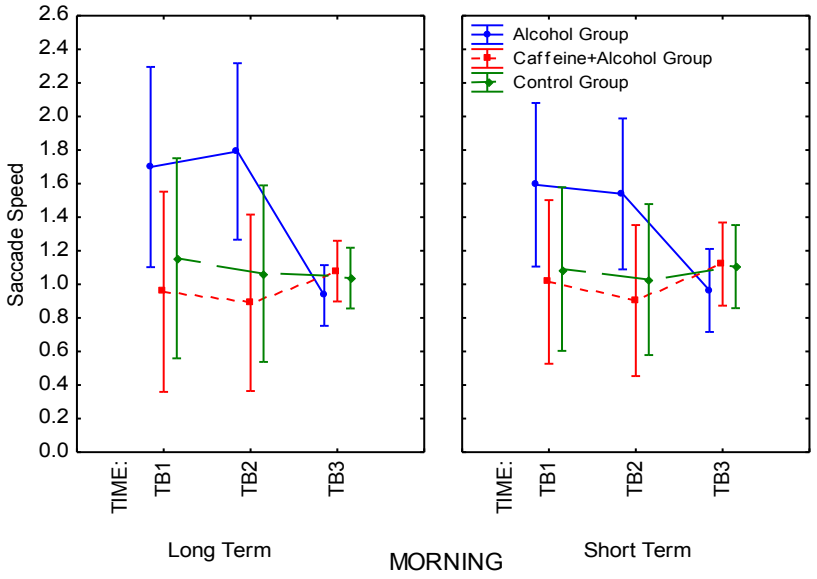

Figure 98: Relative effect of an increased memory rehearsal time on saccade speed for morning experimentation (*alcohol* vs. *caffeine+alcohol: F* (2, 130) = 3.43, p<0.04). Vertical bars denote 95% confidence intervals.

No significant group effects for short term and long term rehearsal were present. A significant time of day effect was however demonstrated between the *alcohol* and *caffeine+alcohol* groups (*F* (2, 130) = 3.43, p<0.04). This effect indicated that alcohol consumption significantly

increased saccade speed during morning experimentation. Further, this relationship indicated a faster saccade speed for long term rehearsal, when compared to the *caffeine+alcohol* group (Figure 98). Saccade speed during evening experimentation was fairly constant in all groups during the evening.

Alcohol consumption imposed a significant integrating effect of task complexity (sequence chunking) and rehearsal period between the *alcohol* and *control* group for saccade speed (F (1, 67) = 6.75, $p<0.02$). This suggests that the higher the complexity of the task, the greater the deficit in saccade speed.

TASK-RELATED EFFECTS

No significant differences in saccade speed were observed between groups. A numerical difference between the *alcohol* and *control* group was observed for saccade speed (F (2, 134) = 2.83, $p<0.07$). Saccade speed was fastest in the *alcohol* group post- alcohol consumption; however, this speed decreased substantially on the declining phase of the alcohol curve (Figure 99).

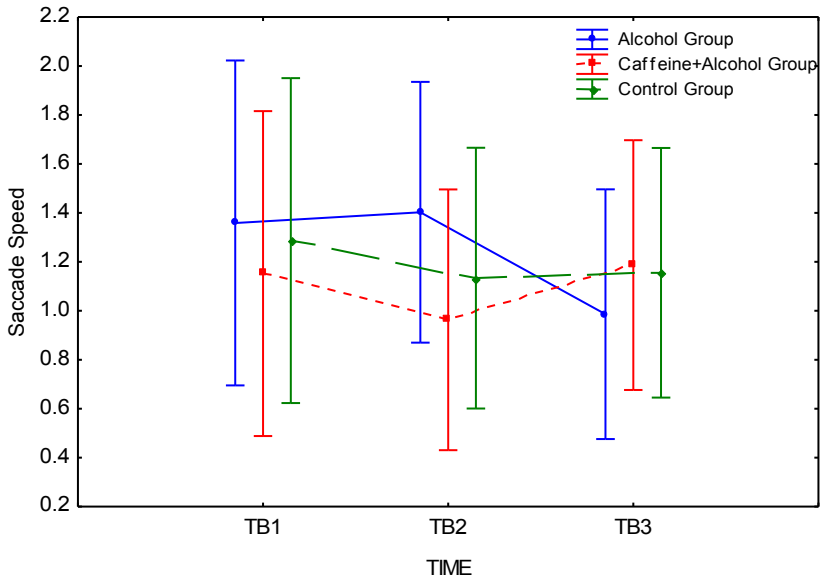

Figure 99: Relative saccade speed during a memory recall task. Vertical bars denote 95% confidence intervals.

As seen in Figure 100, saccade speed during morning and evening experimentation was significantly different when comparing the *alcohol* to the *caffeine+alcohol* group (F (2, 130) = 4.50, p<0.02). It was seen that saccade speed for the *alcohol* group during morning experimentation was significantly faster than the *caffeine+alcohol* group during the same time of day. The ingestion of alcohol causes differing effects upon these groups, with the *caffeine+alcohol* group recording slower saccade speeds post alcohol ingestion (TB2). Further, evening performance indicated a more homogenous saccade speed than that during morning experimentation.

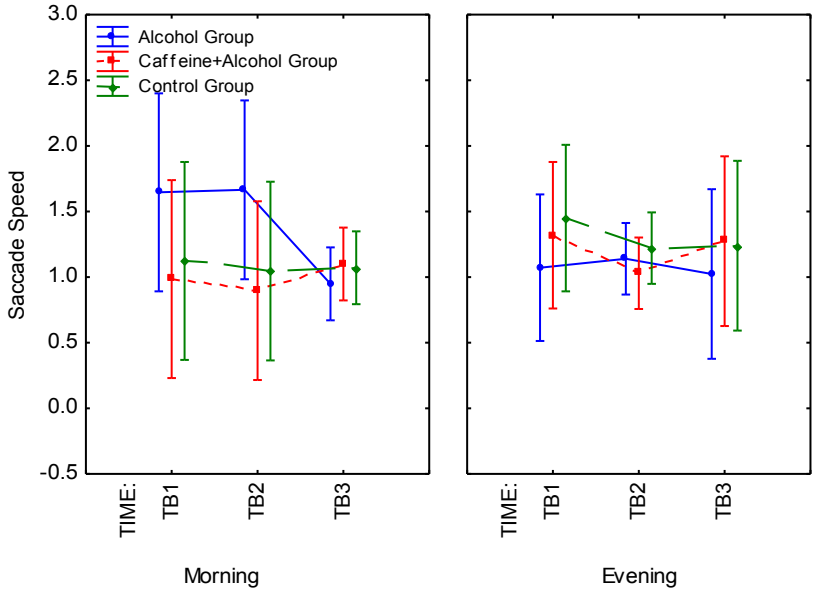

Figure 100: Relative saccade speed during a memory recall task for morning and evening experimentation (*alcohol* vs. *caffeine+alcohol:* F (2, 130) = 4.50, p<0.02). Vertical bars denote 95% confidence intervals.

Saccade Amplitude

DIFFERENTIALLY-RELATED EFFECTS

A significant time of day effect as well as a gender effect was observed in the *caffeine+alcohol* and *control* group comparison, (F (2, 132) = 3.07, p<0.05) and (F (2, 132) = 4.43, p<0.02) respectively. As seen in Figure 101, the *caffeine+alcohol* group when compared to the control group demonstrated a significantly higher difference in saccade amplitude between simple and complex recall during morning experimentation. TB1 and TB2 saccade

amplitude are typical of saccade amplitude being reduced in the complex memory task. Evening saccade amplitude for the *caffeine+alcohol* group showed lesser difference between simple and complex recall whereas the *control* group demonstrated an increasing difference in recall between complexities- indicative of higher saccade amplitude in complex recall.

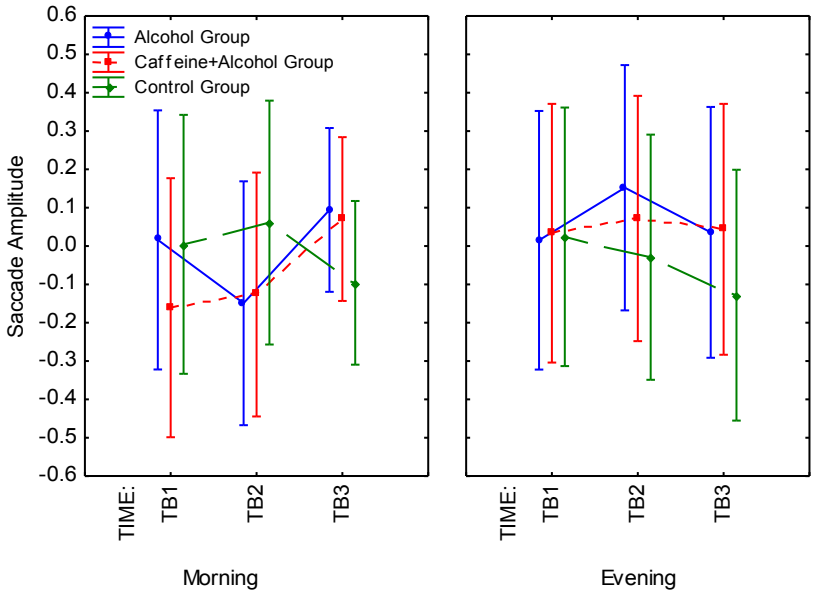

Figure 101: Relative effect of an increased memory capacity demand on saccade amplitude for morning and evening experimentation (*caffeine+alcohol* vs. *control: F* (2, 132) = 3.07, p<0.05). Vertical bars denote 95% confidence intervals.

Saccade amplitude was significantly different for males and females when comparing the *caffeine+alcohol* group to the *control* participants (*F* (2, 132) = 4.43, p<0.02). The *caffeine+alcohol* group showed opposing trends at roughly the same level of difference, however females‟ performance demonstrated higher saccade amplitude in simple recall (positive trend) while the males‟ saccade amplitude was lower during simple recall (negative trend).

A significant effect between the *alcohol* and *control* group was demonstrated in saccade amplitude for long and short term rehearsal (*F* (2, 134) = 3.83, p<0.03). In this comparison (Figure 102), the *alcohol* group‟s trend indicates relatively constant saccade amplitude in both long and short term rehearsal. The introduction of alcohol induced an increase in saccade amplitude during long term rehearsal; the opposite effect was witnessed during short term

rehearsal. The *control* group, on the other hand, showed increased variability in saccade amplitude between simple and complex recall. Collectively, the differences in saccade amplitude between long and short term rehearsal were less variable during long term rehearsal.

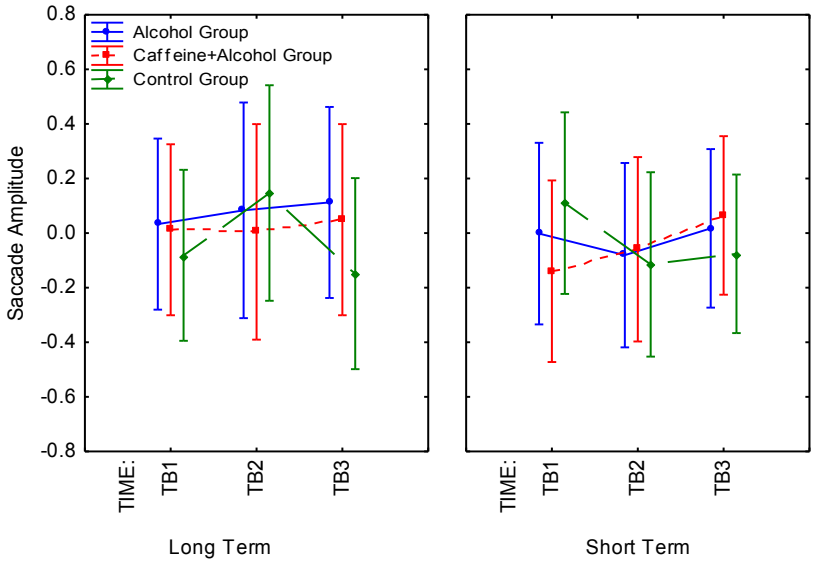

Figure 102: Relative effect of an increased memory rehearsal time on saccade amplitude (*alcohol* vs. *control: F* (2, 134) = 3.83, p<0.03). Vertical bars denote 95% confidence intervals.

TASK-RELATED EFFECTS

Average saccade amplitude did not indicate any general effects. Two significant time of day effects were however demonstrated between the *alcohol* and. *caffeine+alcohol* groups (*F* (2, 130) = 4.64, p<0.04) and in the *caffeine+alcohol* and. *control F* (2, 132) = 3.41, p<0.04).comparisons (Figure 103). Morning experimentation saw the *alcohol* group record the largest saccade amplitude during the memory task. Conversely, the *alcohol* group produced the smallest saccade amplitude during evening experimentation. The *caffeine+alcohol* group recorded the smallest saccade amplitude during morning experimentation, contributing to the significant difference in saccade amplitude observed between the *alcohol* and *caffeine+alcohol* groups (*F* = (2, 130), p<0.04). Further, the difference in saccade amplitude between the *caffeine+alcohol* and *control* groups showed the *control* group to have a higher

saccade amplitude during TB1 and TB2 for both morning and evening experimentation (F = (2, 132), p<0.04).

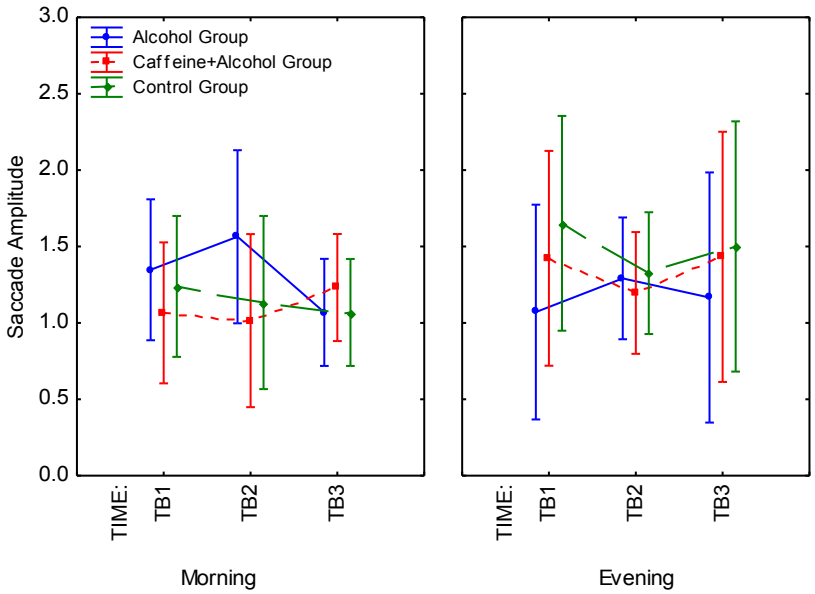

Figure 103: Relative saccade amplitude during a memory recall task for morning and evening experimentation (*alcohol* vs. *caffeine+alcohol: F* (2, 130) = 4.64, p<0.04, *caffeine+alcohol* vs. *control: F* (2, 132) = 3.41, p<0.04). Vertical bars denote 95% confidence intervals.

Fixation Duration

DIFFERENTIALLY-RELATED EFFECTS

Alcohol consumption did not significantly alter fixation duration while performing the memory task.

Fixation duration did not change significantly when performing a recall task with an alteration in rehearsal time. A significant group effect was observed between the *alcohol* and. *caffeine+alcohol* group comparisons between long and short term rehearsal (F (1, 67) = 4.93, p<0.03). The *alcohol* group presented a greater difference in fixation duration during long term rehearsal, indicating longer fixation duration during complex recall (Figure 104). Conversely, the *caffeine+alcohol* group experienced a lesser difference in fixation duration during long term rehearsal, indicative of shorter fixations for complex recall. The difference

between these groups was smaller during short term rehearsal, and demonstrated an inverted trend relative to that observed in long term rehearsal.

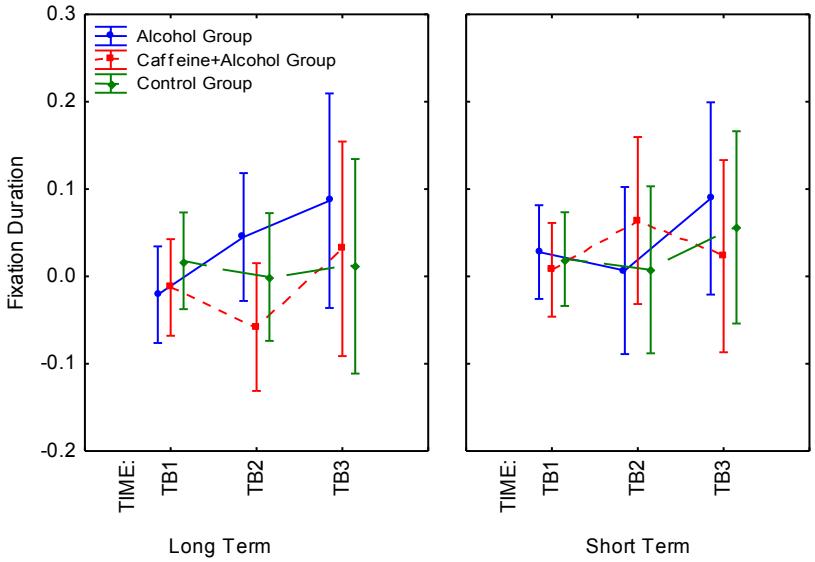

Figure 104: Relative effect of an increased memory rehearsal time on fixation duration (*alcohol* vs. *caffeine+alcohol: F* (1, 67) = 4.93, p<0.03). Vertical bars denote 95% confidence intervals.

A significant gender effect was observed in fixation duration between the *caffeine+alcohol* and the *control* groups (*F* (1, 68) = 4.23, p<0.05). The *caffeine+alcohol* group demonstrated significantly higher differences in fixation duration in female participants for both long and short term rehearsal. *Caffeine+alcohol* males showed a decreased difference in fixation duration throughout test batteries; this difference held true across both rehearsal periods.

TASK-RELATED EFFECTS

Fixation duration did not show significant differences between the *control* and experimental groups.

Motor Performance

Stimulus Response Task

The amalgamation of simple and complex tasks into one test produced only task related oculomotor data. Therefore, results will be discussed as such, describing the average function of simple and complex task performance.

TASK-RELATED EFFECTS

Oculomotor parameters did not reflect any significant effects. Pupil size, saccade speed, saccade amplitude and fixation duration were not sensitive to time of day effects or gender effects across all group comparisons. Furthermore, there were no significant interaction effects for these parameters in any group combination.

Neural Reflex Task

Pupil diameter

DIFFERENTIALLY-RELATED EFFECTS

Alcohol consumption effected a marked difference between simple and complex driving in pupil diameter for the *alcohol* vs. *control* group comparison (F (1, 65) = 3.91, p<0.06). The *alcohol* group demonstrated the most consistent pupil diameter for both complexities of driving during TB1 and TB2. Alcohol consumption increased differential pupil diameter, with a greater diameter during simple task performance (Figure 105). The *control* group shared a similar trend with the *caffeine+alcohol* group, with diameter of the pupil increasing from TB1 to TB2, thereafter decreasing in TB3.

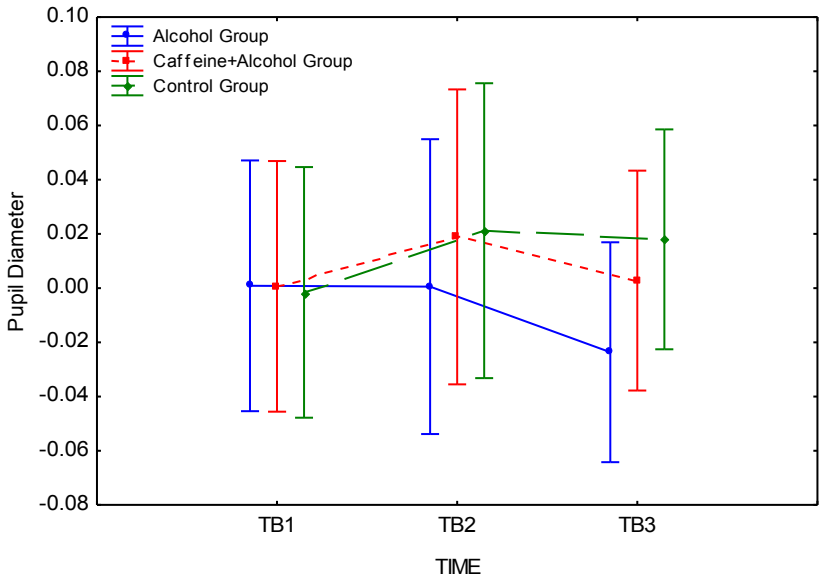

Figure 105: Relative effect of an increased proprioceptive feedback demand on pupil diameter. Vertical bars denote 95% confidence intervals.

TASK-RELATED EFFECTS

Average pupil diameter indicated no significant changes in pupil diameter between all group comparisons.

Saccade Speed

DIFFERENTIALLY-RELATED EFFECTS

Saccade speed was not sensitive to a change in task complexity for the driving simulation neural reflex task.

TASK-RELATED EFFECTS

Average saccade speed demonstrated a significant difference between the *alcohol* and *control* groups (F (2, 90) = 8.25, p<0.01). Alcohol ingestion resulted in an increase in saccade speed within the *alcohol* group when compared to the *control* group during TB2 (Figure 106).

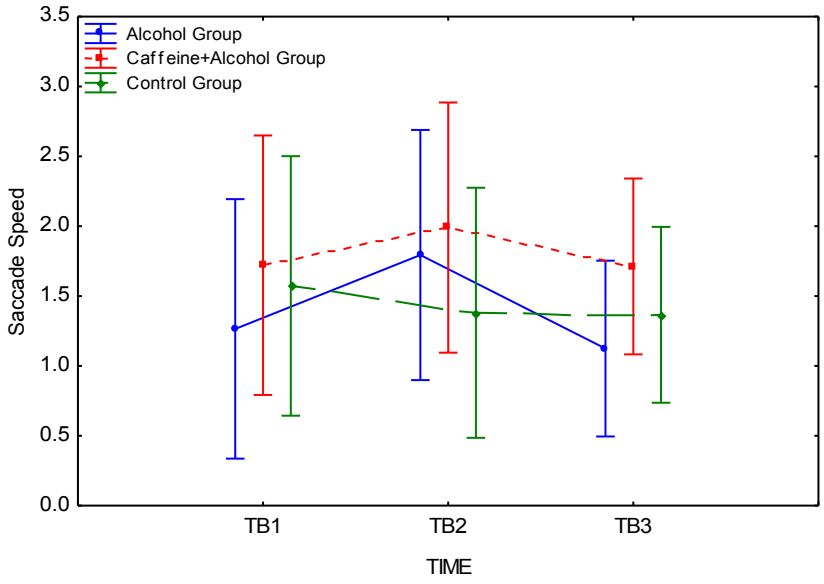

Figure 106: Relative saccade speed for a line tracking task (*alcohol* vs. *control*: F (2, 90) = 8.25, p<0.01). Vertical bars denote 95% confidence intervals.

Saccade Amplitude

DIFFERENTIALLY-RELATED EFFECTS

Saccade amplitude failed to yield significant findings across group comparisons.

TASK-RELATED EFFECTS

Alcohol consumption imposed a significant difference in saccade amplitude when compared to the *control* group (F (2, 90) = 6.25, p<0.01). The *alcohol* group indicated a larger saccade amplitude post- alcohol ingestion and during TB3.

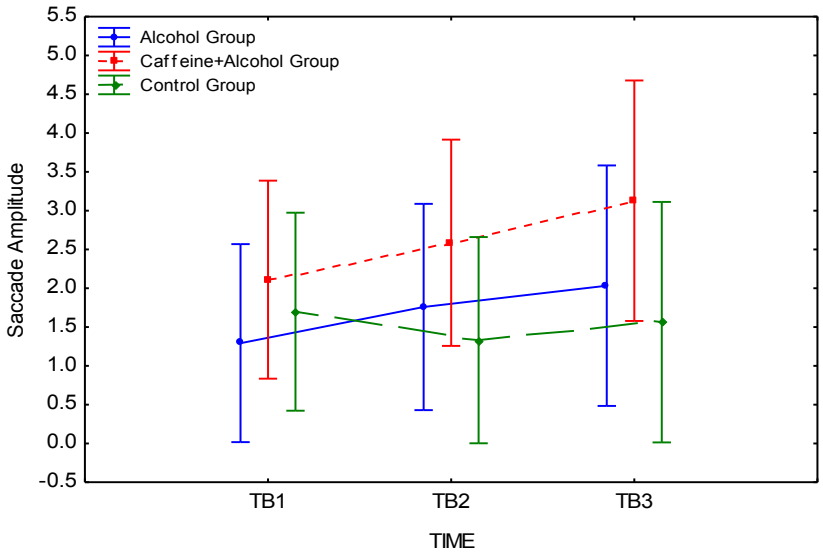

Figure 107: Relative saccade amplitude for a line tracking task (*alcohol* vs. *control*: F (2, 90) = 6.25, p<0.01). Vertical bars denote 95% confidence intervals.

Fixation Duration

DIFFERENTIALLY-RELATED EFFECTS

No significant group, time of day or interaction effects were yielded for fixation duration across all group comparisons. A significant gender effect for fixation duration was demonstrated in the *alcohol* vs. *control* comparison (F (1, 65) = 8.97, p<0.01: see Figure 108). Post- alcohol ingestion, the difference in fixation duration was larger in female participants from the *alcohol* group, indicative of shorter fixations during low sensitivity driving. Conversely, in male participants, the *control* group illustrated a higher difference in fixation duration, also indicative of shorter fixations during complex driving.

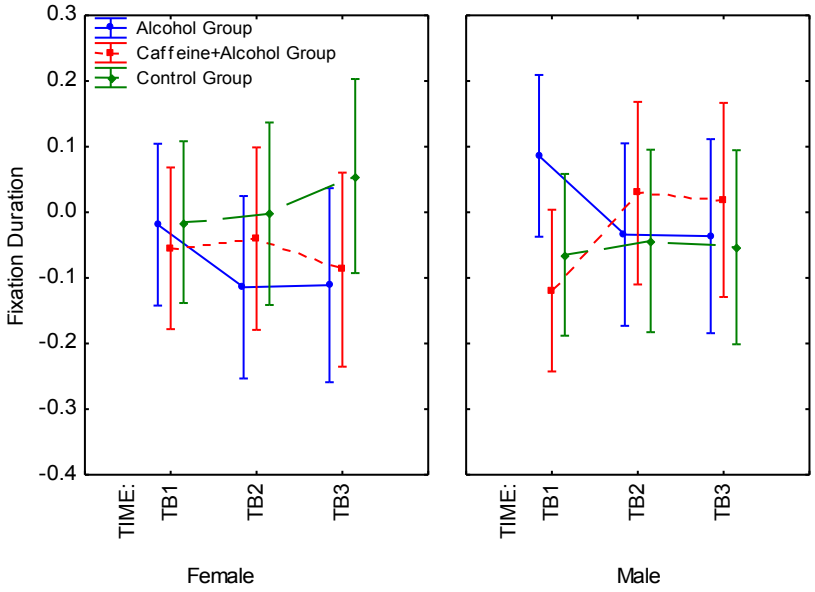

Figure 108: Relative effect of an increased proprioceptive feedback demand on fixation duration for males and females (alcohol vs. *control*: F (1, 65) = 8.97, p<0.01). Vertical bars denote 95% confidence intervals.

Post alcohol consumption, the *caffeine+alcohol* group, when compared to the *control* group, demonstrated a slightly higher difference in fixation duration in male and female participants (F (1, 65) = 3.38, p<0.08). Fixation duration for *caffeine+alcohol* females indicated a longer fixation during high sensitivity driving. The converse was observed for male participants in the same group.

TASK-RELATED EFFECTS

Fixation duration did not show significant effects of gender, time of day or any interactions for these factors for comparison between the *control* and experimental groups.

Summary of oculomotor results

Table XIX: Differential oculomotor results.

DIFFERENTIAL PERFORMANCE			Alcohol vs Control				Alcohol vs Caffeine				Caffeine vs Control			
Dependent Test	Variable	Factor	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening
Accommod-ation	Pupil Size	S vs C	-	-	-	-	-	-	-	-	-	-	-	-
	Saccade Speed	S vs C	-	-	-	□ p<0.07 *	-	-	-	□ p<0.09 *	-	-	-	-
	Saccade Amplitude	S vs C	-	-	-	-	-	ALC ↑ p<0.10 *	-		-	-	-	-
	Fixation Duration	S vs C	-	-	-	-	-	-	ALC ↓ p<0.05	□ p<0.06	-	-	-	-
Visual Detection	Pupil Size	S vs C	-	-	-	-	-	-	-	□ p<0.07	-	-	CAF ↑ p<0.05	□ p<0.02
	Saccade Speed	S vs C	-	-	-	-	-	ALC ↑M p<0.08	-	-	-	-	-	-
	Saccade Amplitude	S vs C	-	-	-	-	ALC ↓ p<0.08 *	-	-	-	-	-	-	-
	Fixation Duration	S vs C	-	ALC ↑M p<0.07 *	-	□ p<0.01	-	-	-	□ p<0.07	-	-	-	□ p<0.08 *
Reading	Pupil Size	S vs C	-	-	ALC ↓ p<0.04 *	-		-	ALC ↑ p<0.02 *		-	-	-	-
	Saccade Speed	S vs C	ALC ↓ p<0.06	-	ALC ↓ p<0.02 *	□ p<0.06	-	-	-	□ p<0.08	-	-	CAF ↑ p<0.05 *	-
	Saccade Amplitude	S vs C	ALC ↓ p<0.08	-	ALC ↓ p<0.02 *	□ p<0.03	ALC ↓ p<0.09 *	-	-	□ p<0.04	-	-	CAF ↑ p<0.01 *	-
	Fixation Duration	S vs C	-	-	ALC ↑p<0.08 *	□ p<0.10	-	-	-	-	-	-	-	□ p<0.05
Memory	Pupil Size	S vs C	-	-	-	-	-	-	-	-	-	-	-	-
		60/90	-	-	-	-	-	-	-	-	-	-	-	-
		SC*60/90	-	-	-	-	-	-	-	-	-	-	-	-
	Saccade Speed	S vs C	ALC ↑ p<0.06	-	-	-	-	-	-	□ p<0.06	-	CAF ↓ p<0.06	-	-
		60/90	-	-	-	-	-	-	ALC ↑ M p<0.04	-	-	-	-	-
		SC*60/90	ALC ↑ p<0.02 *	-	-	-	-	-	-	-	-	-	-	□ p<0.09 *
	Saccade Amplitude	S vs C	-	-	-	□ p<0.06	-	-	-	□ p<0.03	-	CAF ↓ p<0.02	CAF ↓ E p<0.05	-
		60/90	ALC ↓ p<0.03	ALC ↓ p<0.08		-	-	ALC ♂↓ p<0.03	□ p<0.08	-	-	-	-	-
		SC*60/90	-	-	ALC ♂↓ p<0.06	-	-	-	-	-	-	-	-	-
	Fixation Duration	S vs C	-	-	-	-	-	-	-	-	-	-	CAF ↑ M p<0.01 *	-
		60/90	-	-	ALC ↑M p<0.07	□ p<0.03	ALC ↑ p<0.03 *	-	-	-	-	-	-	-
		SC*60/90	-	-	□ p<0.07	-	-	-	□ p<0.09	-	CAF ↓ p<0.10	CAF ↑ p<0.05 *	-	-
Driving Simulator	Pupil Size	S vs C	ALC ↑ p<0.06 *	-	-	-	-	-	-	□ p<0.04 *	-	-	-	-
	Saccade Speed	S vs C	-	-	-	-	-	-	-	-	-	-	-	-
	Saccade Amplitude	S vs C	-	-	-	□ p<0.07 *	ALC ↓ p<0.10 *	-	ALC ↓M p<0.07 *	-	-	-	-	-
	Fixation Duration	S vs C	-	ALC ↓ p<0.01 *	-	-	ALC ↓ p<0.06	-	-	-	-	CAF ↑ p<0.08	-	□ p<0.08 *

ALC = alcohol group CAF = caffeine group ↑ = Increase/ Higher ↓ = Decreased/ Lower ♀ = Female ♂ = Male M = Morning E = Evening □ = Interaction effect * = Effect without time Alcohol = Significant difference p<0.05 (-) = p<0.20

Table XX: Task-relate oculomotor results.

TASK EFFECTS		Alcohol vs Control				Alcohol vs Caffeine				Caffeine vs Control			
Dependent Test	Variable	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening	General	Gender	Morning-Evening	Gender x Morning Evening
Accommod-ation	Pupil Size	-	-	-	-	-	-	-	-	-	-	-	-
	Saccade Speed	-	-	-	-	-	-	-	-	-	-	-	-
	Saccade Amplitude	-	-	-	-	-	-	-	-	-	-	-	-
	Fixation Duration	-	-	ALC ↑ M p<0.08	-	-	-	-	-	-	-	-	-
Visual Detection	Pupil Size	-	-	-	□ p<0.05	-	ALC ♀↓ p<0.03	-	-	-	-	-	-
	Saccade Speed	-	-	-	-	-	-	ALC ↑M p<0.08	-	-	-	CAF ↓E p<0.10	-
	Saccade Amplitude	-	-	-	-	ALC ↓ p<0.08	-	-	-	CAF ↑ p<0.10	-	CAF ↑M p<0.04	-
	Fixation Duration	-	-	ALC ↑M p<0.08	-	-	-	-	-	-	-	-	-
Reading	Pupil Size	-	-	ALC ↓ p<0.10	-	ALC ↑ p<0.09	-	-	-	-	-	-	-
	Saccade Speed	-	-	-	-	-	-	-	-	-	-	-	-
	Saccade Amplitude	-	-	-	-	-	-	-	-	-	-	-	-
	Fixation Duration	-	-	-	-	-	-	-	-	-	-	-	-
Memory	Pupil	-	-	-	-	-	-	-	-	-	-	-	-
	60-90	-	-	-	-	-	-	ALC ↑p<0.10	-	-	-	-	□ p<0.08
	Saccade	ALC ↑ p<0.07	ALC ♂↑ p<0.08	-	□ p<0.08	ALC ↑p<0.09	-	ALC ↑ p<0.02	-	-	-	-	-
	60-90	-	ALC ↑ p<0.08	-	-		-	-	-	-	-	-	-
	Saccade	-	-	-	-	-	-	ALC ↑ p<0.04	-	-	-	CAF ↓E p<0.04	-
	60-90	ALC ↓ p<0.05	ALC ♀↓ p<0.10	-	-	-	-	-	-	-	CAF ↓p<0.04	-	-
	Fixation	-	-	ALC ↑M p<0.07	-	-	-	-	-	-	-	-	-
	60-90	-	-	-	-	-	-	-	-	-	-	-	-
Stimulus Response	Pupil Size	-	-	-	-	-	-	-	□ p<0.02	-	-	-	-
	Saccade Speed	-	-	-	-	-	-	-	-	-	-	-	-
	Saccade Amplitude	-	-	-	-	-	-	-	-	-	-	-	-
	Fixation Duration	-	-	-	-	-	-	-	-	-	-	-	-
Driving Simulator	Pupil Size	-	-	-	-	-	-	-	□ p<0.05 *	-	-	-	-
	Saccade Speed	ALC ↑ p<0.01	-	-	-	-	-	-	-	-	-	-	-
	Saccade Amplitude	ALC ↑ p<0.01	-	-	□ p<0.07 *	ALC ↓ p<0.10	-	ALC ↓ p<0.07 *	-	-	-	-	-
	Fixation Duration	-	-	-	-	-	-	-	-	-	-	-	-

ALC = alcohol group CAF = caffeine group ↑ = Increase/ Higher ↓ = Decreased/ Lower ♀ = Female ♂ = Male M = Morning E = Evening □ = Interaction effect * = Effect without time Alcohol = Significant difference p<0.05 (-) = p<0.20

CHAPTER V

DISCUSSION

INTRODUCTION

The present study was designed to investigate how the consumption of alcohol affects human information processing and if caffeine could antagonise the impairment caused by alcohol. The investigation posed a number of hypotheses regarding alcohol consumption, caffeine-alcohol antagonism and time of day effects on human performance. Firstly, it was predicted that alcohol consumption would result in decreased performance across all information processing parameters and functional resources measured. It was also predicted that caffeine ingestion prior to alcohol consumption would reduce the performance decrements imposed by alcohol. Lastly, it was hypothesised that the time at which alcohol was consumed would demonstrate a greater severity of impairment in morning experimentation as compared to evening experimentation.

Overall, the results of the current experiment tended to support predictions that alcohol impairs processing across the entire information processing chain, and that these effects are not isolated to one specific stage of processing. By contrast, caffeine consumption prior to alcohol consumption did not show antagonistic properties to the impairing effects of acute alcohol consumption and therefore results do not support the proposed prediction. As predicted, alcohol consumption impaired performance to a greater degree during morning experimentation. Furthermore, morning experimentation demonstrated greater decrements in performance as well as larger physiological and oculomotor changes as compared to evening experimentation. Lastly, comparisons between males and females indicated that female participants were more susceptible to alcohol-related effects than were males.

Next, the effects of alcohol, caffeine-alcohol antagonism, time of day effects on alcohol consumption and gender-related differences to alcohol consumption in relation to task-related and differential performance will be discussed in greater detail.

BREATH ALCOHOL CONCENTRATION

Peak blood alcohol concentration, as measured by breath sampling, was reached approximately 45 minutes post alcohol consumption for the *alcohol* and *caffeine+alcohol* groups. Breath alcohol concentration was highest in morning experimentation for both experimental groups; with the *alcohol* group recording higher readings in both experimental sessions in comparison to the *caffeine+alcohol* group. Breath alcohol results produced no significant effects for time of day comparisons or between genders (Table X and Figure 14 and Figure 15).

Studies that administer equivalent doses witnessed a similar trend for time to peak blood alcohol concentration, demonstrating peak measurements between 35 and 45 minutes (Friel *et al*., 1995; Liguori and Robinson, 2001; Vogel-sprott *et al*., 2006; Brumback *et al*., 2007; Fillmore *et al*., 2009). At higher doses (0.6 – 1.0 g/kg), peak blood alcohol concentration has been shown to occur between 60 – 80 minutes (Schweizer *et al*., 2005; Vogel-sprott *et al*., 2006; Fillmore *et al*., 2009). Liguori and Robinson (2001) demonstrated that caffeine consumption, pre alcohol consumption, reduced breath alcohol concentrations when compared to the pure alcohol trials; this result however, was non-significant. This finding is supported by Hasenfratz *et al*. (1993) and Marczinski and Fillmore (2003). In a review of circadian-related studies, Wasielewski and Holloway (2001) reported breath alcohol concentration to be higher for morning consumption, a notion supported by Jones, (1974) and Maisto, *et al.,* (1991). These present results in combination with the previous findings suggest that performance in all respective tasks, should be especially affected between 35 and 45 minutes post alcohol consumption (i.e. between the onset of TB2 and the end of TB2). This suggestion is shown within the current results with the majority of performance tasks showing the greatest impairment during TB2. Similarly, physiological and oculomotor impairment were more exaggerated during TB2.

Gender related differences as evidenced in Figure 15 demonstrate no significant differences between groups. Female participants did however attain higher breath alcohol concentrations throughout experimentation. Mumenthaler *et al*. (1999) support such a finding and state that women are composed of a greater fat mass and less body water than are men of the same

body weights. Because alcohol is dispersed in body water, women reach higher peak blood alcohol concentrations than men after consuming equivalent doses of alcohol. The results show that for certain tasks female participants demonstrate higher levels of impairment compared to male participants. These changes will be discussed in greater depth within the task-related and differentially related sections that follow.

These data suggest that caffeine consumption prior to alcohol ingestion has the ability to reduce breath alcohol concentration. However in the present study, pre-intoxication caffeine consumption did not significantly reduce breath alcohol concentration ($p<0.06$), and therefore caffeine should not be used as a counter measure when consuming alcohol. As observed in Figure 14, caffeine antagonises breath alcohol concentration to a larger extent during evening experimentation, suggesting that the antagonistic capacity of caffeine on breath alcohol concentration is greater during periods of evening alcohol consumption. A possible explanation for this finding, is the rate of metabolism and elimination of alcohol as suggested by Wasielewski and Holloway (2001). Peak circadian rhythm is said to occur between 21:00 and 23:00 and is representative of highest physiological and performance function (Blatter and Cajochen, 2007). At this stage of the circadian rhythm, it is possible that the additive influence of caffeine increases sympathetic modulation and may increase the rate of metabolism and elimination of the drug.

TASK-RELATED EFFECTS

This section looks to discuss significant changes in performance, physiological and oculomotor parameters imposed by acute alcohol consumption. The discussion searches for an explanation of the effects of alcohol on information processing (visual perception, cognition and motor output). Thereafter, these same variables will be discussed with regard to the degree to which caffeine antagonises these performance decrements. Each of these arguments will be discussed with regard to time of day and gender influences.

The impact of alcohol on information processing performance

The impact of alcohol

Performance parameters identified that alcohol consumption increased reaction time during the accommodation task (Figure 16) and resulted in an increased number of stimuli being overlooked in the visual detection task (Figure 24). Further, alcohol consumption increased the number of spelling errors missed while reading (Figure 31). Sensory motor performance illustrated that alcohol consumption effected a significant increase in target deviation (decreased precision) for the stimulus response task (Figure 45) but induced no performance changes while driving.

In terms of physiological measures, the consumption of alcohol significantly increased heart rate frequency while reading (Figure 63). A significant increase in heart rate variability (Low Frequency Power) during memory recall (Table XVI) and a significant decrease in all heart rate variability domains (RMSSD, High Frequency and Low Frequency Power) during the stimulus response task was also observed (Figure 78, Figure 79, and Figure 81 respectively).

Therefore, it would appear that stimuli detection, choice reaction time and accuracy are more sensitive to the impairing effects of alcohol consumption than memory recall, simple reaction time, reading speed and driving ability. Alcohol"s effect on reaction time is supported by Tzambazis and Stough (2000), who demonstrate that alcohol consumption significantly increases simple and complex reaction times as well as inspection time. Jaaskelainen *et al*. (1995) found that the detection of small deviations within stimuli is especially hampered while under the influence of alcohol. Therefore, the additive influence of critical-directional stimulus detection within the accommodation task may have been hampered by the consumption of alcohol, resulting in an increased reaction time. Moreover, coupled with the decrease in cognitive workload (measured by an increase in heart rate variability), it is clear that alcohol consumption deteriorates visual perception during a choice reaction task.

Koelega (1995) observed that vigilance became impaired after alcohol consumption, a finding further supported by (Tzambazis and Stough, (2000). Krull *et al*. (1994) found that alcohol consumption resulted in impaired stimulus detection, suggesting degradation in sensory-perceptual processes and degree of attentiveness. These findings in conjunction with

the present results suggest that alcohol consumption suppresses vigilance and decreases the ability to depict changes in dynamic environments.

The increase in heart rate imposed by alcohol consumption has been supported by a variety of authors (Sayette, 1993; Conrod *et al*., 1997; Conrod, *et al*., 2001) and the effect on heart rate variability to a lesser extent (Koskinen *et al*.,1994; Rossinen *et al*., 1997). The impairment of physiological variables appears to support that heart rate variability is more affected by alcohol consumption than is heart rate frequency.

The increase in heart rate variability in the memory task illustrates that alcohol consumption decreases cognitive effort (Rowe *et al*., 1998); this decrease however, does not affect an individual‟s numerical recall ability. During the stimulus response task alcohol consumption had a similar effect, decreasing both High and Low Frequency Power heart rate variability. This indicates that both parasympathetic and sympathetic activities are affected by alcohol consumption, effectively maintaining the homeostatic relationship in central nervous system modulation. However, a concurrent alcohol-related decrease in RMSSD in the same task, which reflects decreased vagus autonomic control (Task Force, 1996), suggests that sympathetic activity was prominent. Literature shows that a decrease in heart rate variability indicates an increase in sympathetic activation, increased arousal and increased cognitive effort (Task Force, 1996; Rowe *et al*., 1998). Therefore, the alcohol-induced decrease in heart rate variability witnessed during the stimulus response task would suggest that response time and target deviation should improve while under the influence of alcohol. However, as evidenced in the results, this is not the case. Elmenhorst *et al*. (2009) support this finding; demonstrating that target deviation during driving was impaired following alcohol consumption. Therefore, it must be assumed that the increase in cognitive effort is allocated to maintaining response time resulting in a deterioration of target deviation. Furthermore, it may be possible that alcohol consumption effected a behavioural change, in that participants attempted to be as fast as possible hence negating accuracy. This finding suggests that participants experienced a speed-accuracy trade off in response to alcohol consumption, trading off accuracy for the maintenance of reaction time.

These changes suggest that physiological impairment due to alcohol consumption is task dependent, with more complex tasks incurring greater physiological impairment. Moreover, the additive influence of a critical-directional stimulus in the choice reaction task, the changed rehearsal periods in the memory task and the unpredictability of stimuli in the stimulus response task are examples of tasks that show increased sensitivity to alcohol consumption. In all of these tasks alcohol consumption effected significant changes in heart rate variability. Conversely, simpler tasks that require less mental activity show no change in heart rate measures. Mumenthaler *et al*. (1999) state more complex cognitive and psychomotor performance tasks show increased sensitivity to alcohol‟s effects than do simpler tasks. Therefore, the results from the present study are in line with this theory.

The line tracking task indicated that alcohol consumption caused significant increases in both saccade speed and amplitude (Figure 106 and Figure 107). Griffiths *et al*. (1984) state that increased saccadic parameters are indications of increased central nervous system functioning, while Chaplin (2010) attributes decreased saccade velocity to fatigue. Therefore, the significant increase in saccade speed and amplitude suggests that alcohol consumption increases central nervous system function. This notion of increased central nervous system function is supported by decreased heart rate variability and increased heart rate during other task performance. Further, the increase in both saccade speed and amplitude while tracking the road line proposes that alcohol consumption forced participants to make larger eye movements between the tip of the triangle (representing the bonnet of the car) and the road line at greater speeds. This could also suggest an alcohol-related stress response; in that alcohol intoxication causes a behavioural shift, which may represent the need to obtain more regular feedback to maintain goal-directed line-tracking performance.

Caffeine antagonism on alcohol effects

Caffeine consumption prior to alcohol consumption reduced the number of errors overlooked during the reading task, demonstrating fewer spelling errors being overlooked (Figure 31). However, caffeine consumption only demonstrated antagonistic properties in one task (reading) with no antagonism observed in any of the other five tasks.

No significant antagonistic effects were observed in physiological parameters in any of the visual perceptual and memory tasks. A significant decrease in heart rate variability (RMSSD and Low Frequency Power) and an increased heart rate frequency were observed during the stimulus response task. The Low Frequency Component of heart rate variability was significantly higher in the driving related task and the same result was observed for heart rate frequency. Caffeine consumption had no impact on alcohol-related impairment on eye movement data.

Caffeine consumption alone has been shown to reduce response latency during visual monitoring tasks (Baker and Theologus, 1972) and decrease reaction times in signal detection tasks (Kenemans and Lorist, 1995). Brunyé *et al*. (2010) contends that caffeine is a highly reliable antagonist, with regard to its effects on adenosine, elevating levels of arousal and increasing attention (alertness/vigilance). Results herein show caffeine to improve alcohol-related error detection in the reading task, illustrating an increased level of vigilance. Although there are no studies that can support this increased vigilance, Brunyé *et al*. (2010) indicates that caffeine consumption prior to alcohol consumption improves alertness. The present results show that the consumption of alcohol post caffeine consumption seems to negate these performance promoting effects, resulting in limited performance improvements.

It is widely accepted that caffeine stimulates the central nervous system and elevates heart rate (Liguori and Robinson, 2001; Robertson, *et al*., 1981; Ryan *et al*., 2002). These findings are supported by the current increases in heart rate frequency as well as by the decrease in High Frequency Component of heart rate variability. This indicates that caffeine consumption decreased parasympathetic activity, promoting sympathetic modulation and increasing arousal (Task Force, 1996; Rowe *et al*., 1998; Luft *et al*., 2009; Huysamen, 2011). This is further supported by the decreased RMSSD – implying an in increase cognitive effort - in the stimulus response task. This increased stimulation of the central nervous system and increased mental effort did not however improve performance on the associated motor tasks.

Therefore, physiological parameters seem to be more sensitive to caffeine antagonism compared to the performance parameters. Consequently, the antagonistic properties of caffeine on alcohol-related information processing had a negligible influence on task-related

alcohol effects. This result conflicts with previous studies centred on caffeine antagonism (Moskowitz and Burns, 1981; Hasenfratz *et al*., 1993; Liguori and Robinson, 2001; Marczinski and Fillmore, 2003). Interestingly, these authors observed caffeine antagonism despite the implementation of higher doses of alcohol, ranging between 0.6 – 0.65 g/kg and relatively similar doses of caffeine. It would therefore be expected that lower doses of alcohol such as those administered in this study would have experienced a higher degree of antagonism. Perhaps then, caffeine‟s antagonise properties on alcohol are more effective at moderate doses of alcohol.

The impact of time of day on alcohol consumption

The time at which alcohol was consumed had a significant effect on memory recall, showing that alcohol consumption during morning experimentation had a greater impairing effect on recall performance than consumption in the evening (Figure 35). No other performance variables were affected by time of day.

Alcohol consumption increased skin temperature sensitivity depending on the time of day at which experimentation took place. The consumption of alcohol effected a significant decrease in skin temperature for the choice reaction, visual detection and memory tasks. The two visual perceptual tasks indicated a larger decrease in temperature during morning experimentation when compared to the decrease during evening experimentation (Figure 55 and Figure 61). On the other hand the memory task demonstrated that alcohol consumption imposes a hyperthermic and hypothermic effect during morning and evening experimentation respectively (Figure 75).

The temperature results observed in the visual perceptual tasks are supported by Danel *et al*. (2001) and Devaney *et al*. (2003), showing alcohol to induce a hypothermic effect during the day and a hyperthermic effect during night experimentation. Kleitman (1933) demonstrated a correlation between elevated body temperature and improved performance; this theory has also been supported by Blatter and Cajochen (2007). Therefore, a decreased temperature should effect a decrement in performance. Based on this literature, recall performance should be worse during evening experimentation (Wasielewski and Holloway, 2001; Blatter and Cajochen, 2007). However the present finding contradicts the work of Kleitman (1933),

Danel *et al*. (2001) and Blatter and Cajochen (2007). A possible explanation for the fact that performance is impaired under conditions of high body temperature is proposed by Wasielewski and Holloway (2001) and Mumenthaler *et al*. (1999). These researchers contend that a hyperthermic body temperature increases the rate of metabolism of alcohol, consequently raising blood alcohol concentration and increasing the potential for performance impairment. The current findings support this notion in that breath alcohol concentration was highest in the morning coinciding with the lowest recall performance.

Alcohol consumption elicited higher heart rate frequency, increased heart rate variability (Low Frequency Power) and decreased High Frequency Power heart rate variability during the stimulus response task (Figure 77, Figure 80 and Figure 82 respectively). These results were significantly higher during morning experimentation compared to evening experimentation. Similarly, in the driving simulated line tracking task, heart rate frequency was significantly higher during morning experimentation (Figure 86). In addition, heart rate variability (RMSSD and High Frequency power) was significantly lower in the alcohol group, demonstrating higher values in morning experimentation (Figure 88). Therefore, alcohol consumption affects physiological parameters to a greater degree than performance parameters. The physiological changes observed in the sensory motor tasks infer increased sympathetic stimulation, increased arousal and reduced cognitive effort (Rowe *et al*., 1998). Despite these increases in sympathetic nervous system activity, performance was not reduced significantly. Therefore, at these levels of intoxication the time at which alcohol is consumed does not affect performance, but only physiological parameters.

Caffeine antagonism on the interaction between time of day and alcohol effects

The time of the day at which caffeine was consumed did not impose corresponding antagonistic effects on performance for any of the tasks measured. Physiologically, caffeine consumption significantly decreased skin temperature in the visual detection task, showing a greater reduction in temperature during evening experimentation (Figure 61). Caffeine consumption significantly decreased cognitive effort in the reading task demonstrating significantly lower RMSSD in the evening compared to the higher RMSSD observed in the morning (Figure 66). Conversely, alcohol combined with caffeine consumption, induced a

significantly higher RMSSD while performing the line-tracking task in evening experimentation (Figure 88). Lastly, significant decreases in saccade speed and amplitude were observed in the memory task (Figure 100 and Figure 103 respectively). The increases in heart rate variability imposed by caffeine consumption illustrate that caffeine had a larger effect on mental effort during evening experimentation, suggesting that cognitive workload is decreased to a greater extent by caffeine with alcohol during evening experimentation than during the morning.

The results herein indicate that caffeine consumption significantly decreased the speed and amplitude of saccadic parameters during memory recall, demonstrating greater effects in both measures during morning experimentation. Griffiths *et al*. (1984) contend that decreases in saccade speed and amplitude are indications that central nervous system activity has become depressed. From the present results, it is suggested that the combination of alcohol and caffeine together reduced saccadic functions of the eyes to a greater degree than the effect of alcohol alone. As a result and based on no improvements in performance, it seems that caffeine does not have an antagonistic effect on cognitive performance for alcohol consumption, whether in the morning or the evening.

The time of day at which caffeine is consumed prior to alcohol consumption does not give rise to antagonism of visual, cognitive or motor performance. Similarly, the antagonistic effects of caffeine on physiological function are limited in both morning and evening experimentation. However, for morning consumption there is an inclination for caffeine to improve cognitive effort within cognitive and motor based tasks. The physiological responses, on the other hand, seem more sensitive to caffeine consumption during evening experimentation. Further, skin temperature is affected by caffeine consumption: the results are multifaceted, but demonstrate no performance improvements. Lastly, the time of day in which oculomotor parameters are measured shows no difference in response to caffeine consumption as compared to alcohol alone.

Gender and the effects of alcohol

Gender-related differences on the influence of alcohol effected changes only in the visual detection and memory tasks. Visual detection performance showed significant differences in

reaction time (Figure 23) and the number of stimuli overlooked (Figure 26) with female performance demonstrating greater impairment in both measures. The memory task indicates that alcohol consumption effects a significant increase in response delay with males recording significantly slower responses than females (Figure 41).

Alcohol intoxication imposed a numerical difference ($p<0.06$) in heart rate variability (RMSSD) during visual detection, illustrating that inebriation decreases cognitive effort to a greater extent in females than males (Table XVI). A significant change in skin temperature was detected during the reading task, with males recording a lower skin temperature than female participants (Figure 67). While performing the memory task under the influence of alcohol, High Frequency heart rate variability was significantly increased with male participants incurring higher variability when compared to females (Table XVI). In the line tracking task, alcohol consumption decreased heart rate variability for both RMSSD and Low Frequency Power. Female alcohol-only participants‟ demonstrated significantly lower heart rate variability compared to males for both measures. No gender-related differences were found in oculomotor parameters.

Despite the dosage adjustment imposed as per the Widmark equation (Equation 1), significant differences were observed between males and females. It appears that alcohol consumption has a more severe effect on female participants as per the results discussed. The results from visual detection show that for perceptual performance, females show a larger alcohol impairment; a result supported by Mumenthaler *et al*. (1999) and Graham *et al*. (1998). The improved response delay witnessed in females is contradictory to those expressed by Mumenthaler *et al*. (1999), who state that women experience greater deficits in all immediate and delayed recall ability measures. The general increase in response delay has however been supported by Tzambazis and Stough (2000). The decrease in response delay observed in male participants is statistically underpinned by an increased High Frequency Power heart rate variability. Moreover, while performing the memory task male participants experience higher values in heart rate variability than females. This suggests that male participants incurred higher parasympathetic stimulation and decreased arousal and cognitive effort (Rowe *et al*., 1998) thus, increasing response delay. The delayed responses may therefore be attributed to the changes in heart rate variability parameters.

In the line tracking task alcohol consumption induced higher cognitive effort in female participants, therefore requiring a higher investment of effort into the tracking task (Table XVI). This suggests either that male participants were more impaired by the dose of alcohol, or that willingness to allocate attention to the tasks was impaired. The fact that male participants consistently recorded lower breath alcohol concentrations (Figure 15), suggests that the allocation of attention and effort by males must have been the limiting factor in performance.

In conclusion, the results indicate that females experienced a greater severity in impairment in performance parameters. This suggestion is underpinned by higher breath alcohol concentrations recorded in female participants. Conversely, male participants showed increased sensitivity to physiological variables, effectively reducing their capacity to invest effort within the memory and line tracking tasks.

Caffeine antagonism on the interaction between gender and alcohol effects

Caffeine consumption did not antagonise any gender-related differences in visual perception, cognitive or sensory-motor performance parameters. Caffeine consumption induced a significant increase in pupil diameter during the visual detection task with female participants incurring the largest diameters (Figure 92). Skin temperature was the only gender difference antagonised by caffeine; this was observed for the reading and line tracking tasks (Figure 67 and Figure 89). In both of these tasks females recorded the lowest temperatures.

Pupil size has been shown to change with task demands, with an increasing task demand eliciting an increased diameter (Wang, 2009). Therefore, this suggests that the female participants experienced greater demands during the visual detection task, induced by caffeine consumption. Furthermore, the increased pupil diameter suggests that caffeine consumption in females increased concentration and investment effort within the visual detection task. The significantly lower skin temperature in females should, according to Blatter and Cajochen (2007), imply an impaired performance. However, with no significant changes in performance parameters for reading and line tracking tasks, these results hold significance however, at an unacceptable level.

Caffeine consumption did not show any antagonistic effects on oculomotor performance between males and females for any tasks recorded. Therefore based on the results, caffeine consumption does not improve alcohol-related gender differences for visual, cognitive or motor parameters. It does however appear that the combination of caffeine consumption with alcohol consumption induces greater fluctuations in physiological parameters in female participants than in male participants.

DIFFERENTIAL EFFECTS

The impact of alcohol on specific information processing performances

The impact of alcohol

A change in task complexity did not have an effect on visual perception, cognitive ability or motor performance of subjects under the influence of alcohol. Furthermore, alcohol consumption did not effect any changes in object recognition, accommodation of the eye, pattern recognition, memory recall and capacity, motor programming and precision, fine motor control and afferent neural feedback.

Alcohol consumption effected a significant change in heart rate frequency, manifesting in higher heart rates during simple accommodation (Figure 51). This finding implies an increased level of sympathetic stimulation and arousal during simple accommodation (Task Force, 1996). During memory recall, alcohol intoxication imposed a significantly higher heart rate frequency, manifesting higher heart rates for complex recall (Figure 68). In addition, alcohol consumption substantially decreased heart rate variability (RMSSD) between short and long term rehearsal, with short term rehearsal demonstrating lower RMSSD (Figure 72). This result shows that a greater amount of effort was invested during short term rehearsal. The difference between simple and complex recall indicated that complex recall initially induced a higher RMSSD post alcohol consumption. However, 90 minutes post alcohol ingestion, RMSSD was highest for simple recall. A long term rehearsal period induced a higher RMSSD in complex recall throughout experimentation. Finally, alcohol consumption significantly decreased skin temperature for the memory task, however manifesting higher temperatures throughout complex recall (Figure 73).

Alcohol consumption imposed a decrease in saccade speed ($p<0.06$) during reading and memory recall. While reading, saccade speed was initially faster for high resolution; however, 90 minutes post alcohol ingestion saccade speed was significantly faster for low resolution reading. Memory recall shows saccade speed to be faster during complex recall throughout experimentation. Furthermore, saccade amplitude is significantly smaller while under the influence of alcohol, demonstrating larger amplitude for complex recall during long term rehearsal. Conversely, larger amplitude in simple recall was shown for short term rehearsal (Figure 102).

Rohrbaugh *et al*. (1988) posit that early stage impairment by alcohol may be the cause of decreased performance, resulting in a chain- like reaction throught the successive stages of information processing. Similarly, Tzambazis and Stough (2000) contend, based on inspection time and simple vs. complex reaction times, that alcohol impairment of information processing begins in the early stage of information processing. However, these authors go further to say that this impairment only takes place when greater demands are placed on visual spatial attention. This causes a disruption in the ability to shift attention from one spatial aspect to the next, thereby decreasing total information processing. If these results are true, the visual perceptual tasks and their respective complexities should have effected significant changes in one or more of the visual parameters measured. The findings from the present investigation are contrary to both of these theories, in that alcohol consumption does not affect early stage information processing, as shown by performance, physiological and oculomotor performance parameters. This finding is supported by (Steele and Josephs, 1988; Steele and Josephs, 1990; Schweizer *et al*., 2005) who believe that impairment occurs during the central stage of information processing.

The present results suggest that the central stages of information processing are impaired to a greater extent by alcohol when combined with increasing task complexity. Although there are no significant performance changes evidenced, the corresponding physiological and oculomotor changes indicate that alcohol has a greater effect on the body while performing the memory task when compared to the visual perceptual and motor tasks. Alcohol consumption imposed a non-significant decrease in recall performance, demonstrating that memory performance was impaired, however not to a significant degree. Further, this effect

shows that complex recall incurred the greatest deficit in error rate. The increase in heart rate and the concurrent decrease in RMSSD show that central nervous system activity was elevated and that cognitive effort was higher while under the influence of alcohol (Huysamen, 2011); however, this did not improve recall and performance. RMSSD indicates that for short term rehearsal, cognitive effort is highest. This shows that when rehearsal time is short, participants need to invest greater effort to maintain performance. Furthermore, the increase in saccade speed and decreased amplitude between short and long term rehearsal supports the explanation of increased central nervous system activity and increased arousal (Fransson *et al*., 2010 and Griffiths *et al*., 1984).

These results indicate that alcohol consumption at the applied doses (0.4 g/kg) has a limited effect on information processing. As evidenced in the results, when tasks are performed under the influence, a higher- complexity task creates a situation where performance is decreased. The physiological changes associated with the memory task suggest that tasks with increased cognitive requirements are more susceptible to the deleterious effects of alcohol. Furthermore, with no changes in visual perceptual and motor performance, it appears that alcohol does not affect the early and last stages of human information processing compared to the extent to which central processing is affected.

Caffeine antagonism on alcohol effects

The consumption of caffeine prior to alcohol consumption did not antagonise performance parameters in any of the resource specific tasks; this result is inclusive of changes in complexity. The present findings therefore do not concur with those of Liguori and Robinson (2001), who contend that caffeine consumption has limited antagonism at breath alcohol levels of 0.08%. Further, these results contradict the work by Hasenfratz *et al*. (1993), who demonstrated an increased processing rate at breath alcohol concentrations of 0.07%. The antagonism by caffeine on physiological and oculomotor variables is also lacking.

During the neural reflex task, caffeine consumption increased the High Frequency component of heart rate variability, demonstrating increased heart rate variability during high sensitivity steering compared to low sensitivity steering (Table XV). Heart rate frequency was significantly increased by caffeine consumption, showing a higher heart rate for low sensitivity

steering (Figure 83). Caffeine consumption also increased heart rate frequency during memory recall, eliciting a higher heart rate in complex recall throughout experimentation (Figure 68). RMSSD for the memory task was significantly antagonised by caffeine consumption prior to alcohol consumption. As seen in Figure 72, RMSSD was lower when caffeine was consumed for both short term and long term rehearsal, indicating a greater reduction in RMSSD for simple memory recall. Short term rehearsal incurred the greater difference between simple and complex rehearsal demonstrating the lower RMSSD recorded in simple recall. Caffeine consumption prior to alcohol consumption decreased overall skin temperature in the visual detection task (Figure 60).

These results suggest that caffeine consumption affects both heart rate frequency and RMSSD and affects High Frequency Power more than Low Frequency Power. It appears that caffeine consumption prior to alcohol consumption increased the state of sympathetic activation, increasing arousal and cognitive effort while driving. This was consistent with results reported by Rossinen *et al*. (1997) and Segerstrom and Solberg Nes, (2007). Furthermore, the increase in the High Frequency component of heart rate variability suggests that the level of arousal in the simple driving task was lower compared to that in the complex driving task. In addition, it seems task complexity affects heart rate variability and heart rate frequency. The memory task demonstrated that the greater the level of difficulty, the lower the heart rate variability. Moreover, the high complexity memory task (seven numbers) when combined with the more complex rehearsal time (short term rehearsal) accrued the lowest RMSSD values, indicative of the higher cognitive effort. The same result was observed for heart rate variability during driving. The present results are therefore in accordance with complexity-related performance as stated by Mumenthaler *et al*. (1999). However, based on the present results it could be argued that performance is not the only variable affected by an increase in task complexity; rather, that performance and physiological function show variations due to alcohol consumption at increased complexities.

During the neural reflex task, fixation duration was longer ($p<0.06$) when caffeine was consumed compared to alcohol alone. Furthermore, the combination of caffeine and alcohol consumption demonstrated that low sensitivity steering produced longer fixations. In addition, fixations were significantly shorter during short term and long term recall when compared to

alcohol alone. The *caffeine+alcohol* group experienced longer fixations for long term rehearsal and shorter fixations in short term rehearsal. Furthermore, short term rehearsal imposes longer fixations for complex recall whereas in long term rehearsal fixations are longer in simple recall (Figure 104). Therefore, the higher the complexity of the task, the longer the fixation will be, demonstrating a higher level of fatigue; this finding is supported by Schleicher *et al*. (2008).

An interesting result, observed in the visual detection task, stems from reaction time eccentricity. The *alcohol* group, after the introduction of alcohol, produced a negative correlation transforming to a positive correlation from TB2 to TB3 (Figure 27). This suggests that a more centralised "tunnel-like vision" was adopted under post alcohol consumption conditions, allowing *alcohol* participants to detect centralised stimuli much faster than stimuli within the periphery. Conversely, the *caffeine+alcohol* group adopted the opposite strategy, accruing faster reaction times for peripheral stimuli and slower times for centralised stimuli. This may suggest that the stimulating effects of caffeine may have, to a small extent, antagonised the reaction time eccentricity relationship allowing for an improved peripheral performance.

In general, caffeine consumption prior to alcohol consumption does not show improvements in alcohol-related performance. Furthermore, caffeine does not antagonise performance when an increased task complexity is introduced. Caffeine does however show stimulating effects on physiological parameters, promoting general alertness and arousal of individuals.

The impact of time of day on alcohol consumption

Alcohol consumption induced changes in the visual detection task by significantly increasing the number of errors being overlooked during evening experimentation (Figure 24). This finding shows that an increased information density results in decreased stimulus detection and object recognition during evening experimentation, more so than during morning experimentation.

Physiological parameters during the neural reflex task indicate that when under the influence of alcohol heart rate variability (Low Frequency) was significantly reduced, showing evening

experimentation to have the lowest Low Frequency power. Moreover, comparisons between complexities indicated that alcohol consumption induced higher heart rate variability and decreased cognitive effort during low sensitivity (complex) steering compared to high sensitivity steering. A numerical difference ($p<0.06$) in heart rate frequency between morning and evening was demonstrated. This showed that heart rate was lower during evening alcohol consumption and that a higher heart rate for high sensitivity steering was elicited. This however changed over time, with a higher heart rate being elicited for low sensitivity steering 90 minutes post alcohol ingestion. During memory recall, an interaction between complexity and rehearsal time induced a significantly higher heart rate during morning experimentation. Alcohol consumption increased heart rate for both short term and long term rehearsal further resulting in a higher heart rate for complex recall.

The time of day at which alcohol was consumed seemed to significantly affect pupil size, saccade speed and saccade amplitude for the reading task (Figure 94, Figure 95 and Figure 96 respectively). These eye movements increased significantly during morning experimentation, attaining the highest values in low resolution reading and demonstrating that alcohol showed stimulating effects on oculomotoric function during morning experimentation. From these increases we can infer an elevated level of arousal and central nervous system function (Wang, 2009; Griffiths *et al*., 1984). Conversely, evening alcohol consumption elicited depressed oculomotoric function during low resolution reading, incurring decreases in arousal (pupil size) and central nervous system functioning (saccade speed and amplitude). Further to this, these results are underpinned by a non-significant increase in low resolution reading speed demonstrated by the *alcohol* group. Therefore, pattern recognition was less impaired by alcohol during the morning, compared to the evening.

The above results show alcohol consumption to impair performance, physiological and oculomotor parameters to a greater extent during morning experimentation. This was evidenced by the deterioration in eye parameters (pupil size, saccade speed and saccade amplitude) and heart rate frequency. This finding is in accord with the popular theories of Jones (1974) and Maisto *et al*. (1991), who state that alcohol impairment is exacerbated during morning experimentation. However, it appears that in certain circumstances alcohol‟s effects (error rate and depression of heart rate) are greater in the evening. A possible

explanation for deterioration of performance in the evening is explained by the sleep load cycle in the work of Blatter and Cajochen (2007). As an individual‟s time awake increases, a corresponding increase in the need for sleep is found. The increasing sleep load accrued throughout the day, in combination with the alcohol-related downward regulation of the central nervous system, may cause this increase in error rate and the depression of oculomotoric functioning during evening experimentation. Conversely, during morning experimentation, sleep load is reduced, possibly affecting reading error rate and physiological variables to a lesser extent. Field *et al*., (2010) argue that complex tasks are impaired at far lower breath alcohol concentrations compared to more straightforward tasks. Therefore, the exacerbated performance deterioration observed with increased complexity is in accordance with the work of these authors.

Caffeine antagonism on the interaction between time of day and alcohol effects

Caffeine showed few antagonistic effects in subjects‟ responses to alcohol consumption, and exacerbated alcohol impairment in two tasks measured. Caffeine consumption improved error rate in the visual detection task, decreasing the total number of errors overlooked (Figure 24). Conversely, caffeine combined with alcohol consumption increased the difference in reaction times in both morning and evening accommodation, incurring slower reaction times during complex accommodation (Figure 17). Evening experimentation incurred the lowest error rate with an increased visual information density incurring a greater number of errors in both morning and evening experimentation. Furthermore, caffeine consumption increased the number of errors overlooked while reading (Figure 30). The degree of error detection was decreased in the evening indicating worse performance. Error detection was worse for low resolution reading than for high resolution in both morning and evening experimentation. Caffeine consumption did not bring about any changes in any other resource specific tasks.

Performance suggests that visual perception tasks are affected to a greater degree than other tasks by caffeine consumption prior to alcohol. The combination of caffeine and alcohol consumption impairs reaction time and error detection in the visual perception tasks. This shows that at certain times of the day (particularly in the morning) caffeine does not antagonise alcohol‟s effects but rather exacerbates them. Further, complex tasks show

increased sensitivity to the combination of the stimulant and depressant. Based on the visual detection task, caffeine antagonises alcohol-related error rate, reducing the number of errors overlooked, with the lowest error rate during evening experimentation.

The physiological parameters demonstrate that during the neural reflex task, caffeine increased RMSSD ($p<0.06$) and significantly increased both High Frequency heart rate variability as well as heart rate frequency (Figure 83 and

Table XV). Heart rate frequency was significantly higher during low sensitivity driving in the morning. Both heart rate variability measures show caffeine to induce greater heart rate variability for low sensitivity driving and to an extent higher variability during evening experimentation. Irrespective of the time of day, the heart rate frequency results indicate caffeine"s capacity to increase sympathetic activity and arousal; this is supported by Brunyé *et al*. (2010). The increase in High Frequency heart rate variability suggests increased parasympathetic modulation of heart rate, thereby decreasing arousal. Therefore, there seems to be some contention within the present results, with heart rate variability implying reduced mental effort and heart rate frequency showing increased sympathetic activation and arousal. However, with no statistical underpinning in performance and/or temperature data, the extent of caffeine antagonism cannot be quantified. However, the lack of performance changes in combination with the evidenced change in activation and arousal can be interpreted as a successful attempt of participants to regulate performance. This interpretation is supported by Robert & Hockey (1997) in the established compensatory control model.

Fixation duration was significantly longer for complex accommodation when caffeine was consumed during evening experimentation. Further, caffeine significantly decreased pupil size during morning experimentation in the reading task. Saccade speed was depressed by caffeine consumption, eliciting a slower saccade speed in the morning favouring complex memory recall (Figure 98). The longer fixation duration and slower saccade speed suggest that caffeine consumption exacerbates impairment for these oculomotor parameters, implicating caffeine in causing a fatigue- like state when combined with alcohol, effectively slowing eye movements. This theory supports the increase in parasympathetic activity disclosed by heart rate variability, suggesting a decreased level of arousal.

The time of day at which caffeine is consumed seems to have its greatest impact on physiological responses during morning experimental conditions. The combination of caffeine and alcohol consumption increases impairment in visual perception, object recognition, pattern recognition and a number of physiological parameters associated with afferent neural feedback and fine motor control. These results further demonstrate that impairment is greater during periods of morning experimentation and when task complexity is higher.

Gender and the effects of alcohol

Alcohol consumption imposed a greater difference in memory recall between males and females, with male participants recording greater consistency between simple and complex tasks. The differences between five- and seven- number recall demonstrated that female participants experienced a larger impairment from the alcohol dose, causing a lower percentage of correct responses in seven- number recall (Figure 33). Response delay was also effected by alcohol consumption, demonstrating an increased delay by male participants ($p<0.06$) with longer delays observed during complex recall (Figure 39). It appears that male participants adopted a strategy of increasing response time to ensure a higher percentage of correct responses was attained. Furthermore, RMSSD indicated that males experienced a larger difference in heart rate variability ($p<0.06$) between simple and complex recall (Figure 71). This relationship demonstrates that males invested less mental effort during complex recall. Contrastingly, this reduction in mental effort did not impair accuracy in complex recall within this subgroup. With the contradictory performance results and the opposing finding in RMSSD, the difference in performance between male and female subjects may be attributable to a higher level of impairment experienced by the female alcohol group. The memory capacity of each individual has been shown to approximate seven numbers (G. A. Miller, 1956) which would suggest that the complex recall task pushes this capacity limit each time a sequence is presented. Therefore, the consistent decrease in recall performance during seven- number recall can be attributed to the additive impact of alcohol intoxication on the immediate capacity of memory.

Female participants experienced a greater alcohol-related difference in heart rate variability (RMSSD) between simple and complex visual detection, with the simple visual detection

incurring higher heart rate variability (Figure 57). In addition, females showed a greater increase in RMSSD in response to alcohol consumption than male participants, who demonstrated higher heart rate variability within the low resolution reading compared to high resolution (Figure 64). This shows that compared to its effect on males, alcohol reduces the ability of females to invest cognitive effort while reading. Furthermore, female participants overlooked a greater number of errors within the texts, with a higher error rate for low resolution text. Generally then, females when compared to males, demonstrate lower cognitive workloads for the reading and visual detection tasks. Furthermore, alcohol consumption had a greater severity on female heart rate frequency during the neural reflex task; females incurring a higher heart rate with higher complexity. High Frequency heart rate variability was most impaired in males while driving, with males presenting higher heart rate variability during complex driving (Table XV). This demonstrates that male participants experience an increase in parasympathetic activation and hence decreased arousal while driving (particularly in high complexity driving). Fixation duration was significantly reduced by the dose of alcohol during the neural reflex with females eliciting longer fixations: the longest fixations occurring during simple driving.

It appears that when the results for simple and complex task performance are divided between male and female responses, a greater number of significant findings are observed. Furthermore, it appears that alcohol intoxication exhibited greater severity in females, deteriorating performance, physiological and oculomotoric functions to a greater extent than in males. The change in complexity also induces a greater level of impairment, with the majority of results incurring greater effects from increased complexity. This theory is supported by a number of authors (Tzambazis and Stough, 2000; Fillmore and Van Selst, 2002; Schweizer *et al*., 2005). Further, it appears that alcohol consumption effects larger differences between males and females during memory recall compared to the other tests utilised. This is supported by the deterioration in performance in response to complexity, indicated by seven numbers accruing a lower percentage of correct responses than five numbers.

Caffeine antagonism on the interaction between gender and alcohol effects

In the neural reflex task caffeine consumption improved information capacity to a greater extent in female participants (Figure 49). In addition, during reading caffeine imposed a numerical difference between males and females for error detection. This finding reflected that female participants tended to miss a larger number of errors, with a greater percentage of errors being overlooked during low resolution reading. During memory recall, caffeine consumption increased response delay, showing female participants to incur the highest response delay (specifically slower in complex recall). This result indicates that caffeine consumption in males improves alertness, and allows for faster initiation of the response. In short term and long term rehearsal, female participants still incurred the longest delay, with short term rehearsal incurring the greatest delay by this sub group. Therefore, the delay between sequence presentation and response initiation is impaired by caffeine to a greater extent when the rehearsal period is shortened. This implies that with a shorter rehearsal period, the confidence in initiating response is reduced, thereby increasing response delay.

In all performance measures, caffeine antagonised only one parameter – information capacity – suggesting that the antagonistic properties of caffeine on alcohol are limited. During the reading and memory tasks, caffeine consumption in combination with alcohol deteriorated performance to a greater extent than alcohol alone. Therefore, caffeine consumption does not show antagonistic effects for an alcohol dose of 0.4 g/kg, in favour of a particular gender. With no evidence for improvement in gender-related differences for caffeine antagonism this finding is in agreement with Marczinski and Fillmore (2006). The general finding of caffeine not having antagonizing properties on performance is contrary to those demonstrated in previous literature (Moskowitz and Burns, 1981; Hasenfratz *et al*., 1993; Liguori and Robinson, 2001; Marczinski and Fillmore, 2003).

A numerical difference in High Frequency Power heart rate variability was observed between males and females for memory recall. Caffeine consumption decreased heart rate variability (High Frequency) in males more than in females. Further this interaction showed that High Frequency Power was elevated to a greater extent during simple recall. As previously stated, a decrease in High Frequency heart rate variability indicates a decreased parasympathetic

nervous system response, promoting increased arousal (Rowe *et al*., 1998). This increase in arousal explains the reduced response delay elicited in male participants, in that the increased alertness and mental effort observed in males allowed for a faster response. This statement is further underpinned by skin temperature results. Kleitman (1933) postulated the relationship between increased temperature and increased performance and this finding has received support from a variety of authors (Blatter and Cajochen, 2007). The results herein demonstrate skin temperature to be significantly affected by the consumption of caffeine and alcohol, producing higher temperatures for both short term and long term rehearsal in male participants. In this, the increased temperature could be seen as a contributing factor to the improved performance in male participants.

In conclusion, the results suggest that caffeine consumption prior to alcohol consumption shows improvement in male performance to a greater degree than female performance. However, the degree of caffeine antagonism as a whole is limited, and does not demonstrate the antagonistic properties previously suggested (Moskowitz and Burns, 1981; Hasenfratz *et al*., 1993; Liguori and Robinson, 2001; Marczinski and Fillmore, 2003).

GENERAL DISCUSSION

Alcohol consumption produced a greater number of impairments in performance for task-related changes in information processing compared to changes in relation to task complexity (differential). The changes in performance, physiological and oculomotor variables post alcohol consumption indicate that each of the stages in human information processing experiences varying degrees of impairment due to alcohol consumption. As illustrated in Table XXI, the visual perception stage in task-related performance was more severely affected by alcohol consumption than the cognitive and motor stages, evidencing three performance decrements. The motor stage of information processing, shows performance impairment in only the stimulus response task however with concurrent changes in physiological and oculormotor parameters. It should however be noted, that due to the combination of simple and complex tasks into a collective task, the physiological and oculomotor data only reflects the average function. This data therefore cannot be used in explanation of differential results.

Table XXI: Effects of Alcohol on information processing stages for task-related performance (**x** denotes significant main effect where p< 0.05 and * p<0.06).

	Choice Reaction	Visual Detection	Reading	Memory	Stimulus Response	Line-Tracking
TASK-RELATED EFFECTS						
PERFORMANCE PARAMETERS						
	x	x	x		x	
PHYSIOLOGICAL PARAMETERS						
HRF			x			
rMSSD					x	
HF Power					x	
LF Power					x	
Skin Temperature						
OCULOMOTOR PARAMETERS						
Pupil Size						
Saccade Speed						
Saccade Amplitude				x		
Fixation Duration						

Differential analysis showed that a change in complexity led to greater alcohol-related impairment in physiological and oculomotor parameters and had a lesser effect on performance parameters (Table XXI). Alcohol consumption had significant effects on cognitive performance as measured in the memory task with increasing complexity posing even greater significance on memory performance. As evidenced by Table XXII alcohol consumption seems to affect central information processing to a greater degree when considering differential performance compared to task-related performance.

Table XXII: Effects of Alcohol on information processing stages for differential performance (**x** denotes significant main effect where p< 0.05 and * p<0.06).

	Accommodation	Stimulus-Noise distinction (visual)	Visual pattern recognition	Memory	Motor programming	Neural Reflex
DIFFERENTIAL EFFECTS						
PERFORMANCE PARAMETERS						
					*	
PHYSIOLOGICAL PARAMETERS						
HRF	X			X		
rMSSD				X		
HF Power						
LF Power						
Skin Temperature				X		
OCULOMOTOR PARAMETERS						
Pupil Size						*
Saccade Speed			*	X		
Saccade Amplitude				X		
Fixation Duration						

Collectively, alcohol impairment seems to have greater impact on the early and central stages of information processing in comparison to the motor output stage. Rohrbaugh *et al*. (1988) attributes alcohol impairment on information processing to an early stage breakdown, resulting in a chain-like effect throughout the remainder of processing. The results from the current study tend to be in line with this researcher, in that vigilance and choice reaction time were significantly affected by alcohol consumption. These two tasks require large visual input, with a small degree of decision making and motor response. Therefore the breakdown in the ability to detect these stimuli transfers through the chain, effectively increasing reaction times and error rates.

Moreover, Tzambazis and Stough (2000), demonstrate that alcohol slows early stage information processing that involves perceptual speed. This finding is supported by the increase in reaction times in the visual detection and accommodation tasks. Furthermore, Jaaskelainen *et al*. (1995) observed a similar finding, in that early stage information processing was impaired by alcohol as demonstrated by the reduced capacity to detect

critical stimuli. A similar result was witnessed in this study by way of increased choice reaction time in the accommodation task. Steele and Josephs (1990) proposed a model relating to alcohol‟s influence on attentional processes. According to this attention-allocation model, alcohol intoxication restricts an individual‟s focus of attention to only the most prominent cues in the environment such that all available cues are not fully processed. Resultantly, alcohol impairs the capacity to process all environment signals, and hence only certain cues enter the processing chain. This theory explains the decrement in performance in both the visual detection and accommodation tasks, in that the ability to process all stimuli within the visual detection tasks and the capacity to detect subtle changes in the accommodating stimuli were impaired by the consumption of alcohol. Similarly, error detection rate in the reading task indicated that alcohol consumption significantly increased the number of spelling errors missed. These results demonstrate a limited capacity to detect and process all experimental stimuli while under the influence of alcohol and the current study therefore agrees with Steele and Josephs (1990).

Schweizer *et al*. (2005) reported the theory that central processing was affected to a greater extent than was early stage information processing. This observation has also been supported by Josephs and Steele (1988) and Fillmore and Van Selst (2002) whose explanations have centred on cognitive constraints limiting performance while under the influence of alcohol. Schweizer *et al*. (2005) concluded that two tasks performed in rapid succession to one another will show an impaired performance on the secondary task. The memory task in this study demonstrates a non-significant deterioration in memory capacity and recall ability. The memory task showed a greater sensitivity to the change in complexities, recording greater performance decrements at higher levels of complexity. The greatest decrement in performance and physiological functioning was found for a short rehearsal period in the complex recall trial. Although the methodologies employed in this study and that of Schweizer *et al*. (2005) are distinctly different the results demonstrate similarities. The short term rehearsal represents a similar finding to Schweizer *et al*. (2005) in that a decrease in time between sequences resulted in a larger impairment in performance. The cognitive results in the present study are underpinned to a greater degree by physiological change in comparison to the visual perception tasks utilised. This physiological underpinning suggests

that alcohol impairs cognitive performance and hence the central stage of processing to a greater extent than the early and later stages of information processing.

Sensory Motor performance showed greater performance impairment in task-related measures and had statistical underpinning in physiological functioning. Motor programming showed an increase in programming speed ($p<0.06$) with an accompanying significant increase in target deviation. Tzambazis and Stough (2000) found a similar result in that alcohol consumption decreased visual motor coordination, impairing the ability to produce movements required to respond to critical stimuli. Furthermore, Elmenhorst *et al*. (2009) demonstrated significant increases in target deviation while driving under the influence of alcohol. Therefore, alcohol consumption increased response time as well as target deviation. This relationship demonstrates the well-established speed-accuracy trade off in performance (Schmidt and Wrisberg, 2008). Similar speed-accuracy trade-offs have been found in previous alcohol related studies. Tiplady *et al*. (2001) found that alcohol elicited an increase in performance speed but at the expense of an increased error rate. The present results imply that alcohol may have induced a behavioural change within participants, in that while attempting to maintain speed participants incurred a subsequent decrease in accuracy. This suggestion is however not statistically underpinned by decreased cognitive effort (increased heart rate variability): rather, cognitive effort is increased in this instance.

Egeth and Kahneman (1975) contend that tasks at different levels of complexity elicit different degrees of arousal and demand different amounts of attention and effort. The differential results from the present investigation are in agreement with this theory. The present results indicate that complex task performance induced higher physiological costs and showed greater impairment in performance when compared to simple task performance. Alcohol consumption did not induce any significant changes in performance variables when task complexity was higher. Therefore, in line with the differential testing approach, the change in a single aspect of each task did not significantly change performance when alcohol was introduced. As performance in simple and complex versions of each task was not significantly different and because each complexity was affected to a similar degree by alcohol consumption, the resources used in each stage of information processing were not

depleted. Therefore, alcohol consumption for the dose implemented in this study, did not induce performance-related resource depletion.

Alcohol consumption did, however, induce significant changes in physiological parameters between the two complexities. Alcohol consumption generally elicited an increase in heart rate frequency while inducing a decrease in heart rate variability (RMSSD). In a majority of these instances, complex task performance elicited higher physiological responses. These results have been supported in past research: Sayette (1993) demonstrated an increase in heart rate frequency, so too did Conrod *et al*. (1997) and (2001). Conversely, Koskinen *et al*. (1994) demonstrated decreases in RMSSD as did Rossinen *et al*., (1997). The increase in heart rate frequency and decreased heart rate variability indicate that sympathetic activity is prominent, implying increased arousal and a greater investment of mental effort within tasks (Task Force, 1996 and Rowe *et al*., 1998). This increase in sympathetic stimulation and arousal and the accompanying increase in mental effort, would suggest that performance should improve. However no improvement was observed between simple and complex comparisons. A possible explannation for this increased arousal and mental effort with no appreciable change in performance can be found in the compensatory control mechanism as hypothesised by Robert & Hockey (1997).

Robert & Hockey (1997) states that performance protection may occur as difficulty or environmental disturbances increase; however, the protection is at a cost to the performer. This author states that effective performance under stress is typically accompanied by high levels of physiological activation and subjective strain. With alcohol inducing a stress-like state, this model is applicable to the current study. Therefore, despite the impairment caused by alcohol consumption, participants invested greater mental effort during the memory and neural reflex task, in turn increasing sympathetic stimulation (decrease in heart rate variability and increased heart rate) resulting in the maintenance of performance. Thus, the maintenance of performance under complex task conditions is an active process controlled by the participant, requiring the management of cognitive resources through the mobilisation of mental effort.

The antagonistic properties of caffeine on alcohol consumption were not as evident as other studies suggest (Moskowitz and Burns, 1981; Hasenfratz *et al*., 1993; Liguori and Robinson, 2001; Marczinski and Fillmore, 2003). Despite the lower dose of alcohol administered in this investigation, the effects of prior caffeine consumption on alcohol impairment were limited. Caffeine illustrated a single true antagonistic effect on performance, demonstrating decreased error rate while reading. Based on this single result, it would be unrealistic to conclude that caffeine consumption prior to alcohol consumption has the ability to antagonise the detrimental effects of alcohol. As previously discussed, in certain cases caffeine showed a tendency to exacerbate the effects of alcohol. This result was witnessed in both morning and evening experimentation and as a factor of gender.

The time of day at which alcohol is consumed has shown to compound the effects of alcohol consumption. The present results show that alcohol consumption incurred greater breath alcohol concentrations during morning experimentation, a finding that is in accordance with other alcohol trials (Jones, 1974; Maisto, *et al.,* 1991; Wasielewski and Holloway, 2001). These higher breath alcohol concentrations resulted in a greater impairment during morning experimentation in a majority of the measures recorded. Therefore, it can be concluded that the consumption of alcohol in the morning has greater implications for performance, physiological and oculomotor functioning compared to evening alcohol consumption.

Despite an attempt to standardise alcohol consumption, by use of the Widmark equation, differences between males and females in breath alcohol concentration were present. The breath alcohol concentrations recorded, although not significant, demonstrated a higher impairment in female participants. These results are in support of those demonstrated by Graham *et al*. (1998) and Mumenthaler *et al*. (1999). These increased breath alcohol concentrations transferred into performance, physiological and oculomotor parameters. Alcohol consumption impaired female participants‟ performance to a greater extent than males‟ performance. Similarly, changes in physiological and oculomotor variables in response to alcohol were larger for female participants than for males. These findings are supported by previous gender-related studies (Mumenthaler *et al*., 1999).

DELIMITATIONS

The sample size was limited to 108 participants (54 male and 54 female), with an age range between 19 and 30 years of age. Further, no significant group differences for anthropometrics, morning-eveningness, caffeine consumption as well as drink familiarity and tolerance were present between the two experimental and control groups. Therefore, three groups that were homogeneous were utilised in this study. This allowed for a decrease in variability within the results, allowing for differences in performance and physiological functioning to be attributed to the varying conditional effects tested.

Participants were requested to refrain from drinking any amount of alcohol and/or caffeine as well as to avoid any form of strenuous physical activity 24 hours prior to experimentation. Furthermore, participants were instructed to eat approximately four hours prior to testing to ensure each participant had some nourishment but at the same time was not completely satiated, thus affecting the rate of alcohol metabolism. Whether or not participants followed these instructions was beyond the control of the researcher. Although it was difficult to control for the exact rate of alcohol absorption, drink familiarity and tolerance, participants were limited to individuals who had experience with alcohol consumption but were not classified as „binge drinkers".

This study implemented a mixed repeated/non-repeated measures design. Two experimental groups were used in this study to perform the experimental testing and results were compared to a control group. There are various advantages and disadvantages of repeated vs. non-repeated design: for the purpose of this study a mixed design was better suited. Task-learning effects are often experienced when participants are exposed to numerous trials of a given task. In adopting this mixed design, the number of times each participant was exposed to the same task was reduced, hence minimizing any learning effects.

Furthermore, in an attempt to further reduce order and learning effects participant testing was permutated for test times and between groups, ensuring the order of testing was randomised. This was ensured by developing experimental conditions and procedures that were standardised for each participant, contributing to the reliability of the study. Lastly, experimentation occurred under controlled laboratory conditions at the same times each day,

negating the effect of ambient factors such as temperature. In this environment, it was possible to standardise methodological factors. Furthermore, the permutation table in conjunction with the standardised experimental times aided in the control of circadian masking effects.

Exclusion criteria for this investigation included: Participants who possessed any form of drinking dependence or drinking disorder, and those who consumed more than 1200 mg caffeine per day. Participants who were dyslexic, wore glasses, were colour blind, or were not proficient in reading were excluded as well. Participants who could not understand English and individuals who were computer illiterate were also excluded from this study.

LIMITATIONS

As a matter of fact it is impossible to control for all extraneous variables. It was however the researcher‟s aim to meticulously control as many as possible of these variables that could have negatively affected the final results. However due to the varying effects that alcohol imposes on each individual, certain limitations present in this study could not be avoided. Therefore, when analysing the data the following limitations had to be considered:

The mixed design principal resulted in a larger variability between group comparisons. This factor could have been reduced had a repeated measures design been implemented. However, this confounding issue pertaining to reliability was overcome by utilising a large sample size (n=108). Furthermore, the variability with which alcohol impairs different individuals could not have been avoided, despite the researcher‟s attempt to attain as homogenous a group as possible for each of the groups tested. However, if a repeated measures design had been implemented, learning effects gained from conducting the test battery four times per session and in three different conditions would have reduced the number of significances observed. A further disadvantage in the implementation of a repeated measure design would have been participant recruitment. Recruiting participants to attend six 2 hr. 45 min. sessions would have been difficult given that no remuneration was offered.

The participants who volunteered for this study were taken from the Grahamstown community and more specifically the students of Rhodes University. The age of the participants was

limited to individuals between the ages of 19 and 30. These participants were therefore not fully representative of the entire population but to test the entire age range of alcohol consumers was beyond the scope of this study and would have added further variance. Moreover, the impact of alcohol on information processing performance was not expected to be dependent on age, despite the general effects of age on performance and alcohol sensitivity.

Each individual employed in this investigation had a varying level of tolerance to alcohol and the effects that alcohol exhibits (the same can be said for caffeine). A drink familiarity and tolerance questionnaire (DFTQ) and a caffeine consumption diary were therefore administered to each participant before participant selection. This was in an attempt to establish the tolerance level of each individual and to select a group that shared similar drinking practices. These questionnaires were implemented to obtain a sample that experienced similar tolerance levels, thereby increasing the reliability of the results obtained.

The rate at which alcohol is absorbed by the metabolism of each individual could not be controlled. Therefore, each individual was administered a unique amount of alcohol to effect a similar level of intoxication between participants. This quantity of alcohol was calculated and administered to each participant using the Widmark equation. This equation is scientifically underpinned and based on each participant‟s body weight and a gender-related diffusion factor (Equation 1). However, the administered amount may not be a direct representation of the blood alcohol concentration that is aimed for. This may result in variations in the effected breath alcohol concentrations in each participant. This issue could have been avoided by the implementation of a more in-depth pilot study, where each individual‟s dosage could have been perfected and time to peak blood alcohol concentration measured. This however would have incurred huge costs, both in terms of time and financial costs. The rate of elimination was however controlled, and participants were not allowed to urinate during the testing sessions. Participants were advised to go to the bathroom before testing commenced.

Breath alcohol concentration was measured using a breathalyser ensuring that participants had reached the required level of intoxication. Although a breath alcohol analyser of the highest quality and latest technology was used, these results are not considered as reliable

as direct measurement of blood alcohol concentration. However, given the nature of this study, breath analysis served the intended purpose.

The laboratory settings may have affected the degree of effort each participant invested within the experimental protocol, compared to if testing had occurred in a real life situation. However, the controlled nature of laboratory testing supplied a safe testing environment, reducing associated-risks to each participant.

The resource specific tasks utilised in the current methodology were designed within the Department of Human Kinetics and Ergonomics and are yet to be validated. Therefore, the results may be difficult to compare to previous results obtained from more established test methods. The use of such tasks however, would not have allowed for the manipulation of specific functional units in order to test possible effects of alcohol and caffeine. Each task was formulated using sound scientific principles. Furthermore, these specific tasks have been utilised within the aforementioned Department and have shown to induce changes in physiological and performance parameters in a number of varying research domains.

A possible confounding factor of these tasks pertains to the durations within each task. This duration may not have been long enough to induce changes in performance, physiological and oculormotor parameters and may have contributed to the limited of statistical backing observed in the present results.

RESPONSE TO STATISTICAL HYPOTHESES

Hypothesis 1:

a) This first hypothesis states that perceptual, cognitive and sensory-motor performance will be equal for both alcohol and non-alcohol conditions.

With regard to the impact of alcohol consumption on task-related effects, the following significant differences force the rejection of the null hypothesis for the following variables.

Visual perception: Increased reaction time. Increased number of errors overlooked. Increased number of spelling errors missed.

Sensory-motor output: Increased target deviation

b) This hypothesis states that the physiological parameters measured in perceptual, cognitive and sensory-motor tasks will be equal for both alcohol and non-alcohol conditions.

With regard to the impact of alcohol consumption on task-related effects, the following significant differences force the rejection of the null hypothesis for the following variables.

Visual perception: Increased heart rate frequency.

Cognition: Increased heart rate variability (Low Frequency Power).

Sensory-motor output: decreased heart rate variability (RMSSD, High Frequency Power and Low Frequency Power).

With regard to the impact of alcohol consumption on differentially-related effects, the following significant differences between simple and complex task performance force the rejection of the null hypothesis for the following variables.

Visual perception: Increased heart rate frequency.

Cognition: Decreased heart rate variability (RMSSD), increased heart rate frequency and decreased temperature.

c) This hypothesis states that the oculomotor parameters measured in perceptual, cognitive and sensory-motor tasks will be equal for both alcohol and non-alcohol conditions.

With regard to the impact of alcohol consumption on task-related effects, the following significant differences force the rejection of the null hypothesis for the following variables.

Cognition: Decreased saccade amplitude and increased saccade speed.

Sensory-motor output: Increased saccade speed and saccade amplitude.

With regard to the impact of alcohol consumption on differentially-related effects, the following significant differences between simple and complex task performance force the rejection of the null hypothesis for the following variables.

Cognition: Increased saccade speed, decreased saccade amplitude

Hypothesis 2:

a) This hypothesis states that perceptual, cognitive and sensory-motor performance will be equal for both caffeine and non-caffeine conditions.

With regard to the impact of caffeine consumption prior to alcohol consumption on task-related effects, the following significant differences force the rejection of the null hypothesis for the following variables.

Visual perception: Decreased number of errors missed.

b) This hypothesis states that the physiological parameters measured in perceptual, cognitive and sensory-motor tasks will be equal for both caffeine and non-caffeine conditions.

With regard to the impact of caffeine consumption prior to alcohol consumption on task-related effects, the following significant differences force the rejection of the null hypothesis for the following variables.

Sensory-motor output: Decreased heart rate variability (RMSSD), increased Low Frequency Power heart rate variability and increased heart rate frequency.

With regard to the impact of caffeine consumption prior to alcohol consumption on differentially-related effects, the following significant differences between simple and complex task performance force the rejection of the null hypothesis for the following variables.

Visual perception: Decreased temperature.

Cognition: Decreased heart rate variability (RMSSD), increased heart rate frequency and decreased fixation duration.

Sensory-motor output: Increased heart rate variability (High Frequency Power) and increased heart rate frequency

c) This hypothesis states that the oculomotor parameters measured in perceptual, cognitive and sensory-motor tasks will be equal for both caffeine and non-caffeine conditions

With regard to the impact of caffeine consumption prior to alcohol consumption on differentially-related effects, the following significant differences between simple and complex task performance force the rejection of the null hypothesis for the following variables.

Cognition: Decreased fixation duration.

Hypothesis 3:

a) The final hypothesis states that perceptual, cognitive and sensory-motor performance will be equal for both morning and evening experimentation.

With regard to the impact of alcohol consumption on task-related effects, the following significant differences between morning and evening experimentation force the rejection of the null hypothesis.

Cognition: Decreased memory recall.

With regard to the impact of alcohol consumption on differentially-related effects, the following significant differences observed for simple and complex task performance between morning and evening experimentation force the rejection of the null hypothesis for the following variables.

Visual perception: Increased number of stimuli overlooked.

b) This hypothesis states that the physiological parameters measured in perceptual, cognitive and sensory-motor tasks will be equal for both morning and evening conditions.

With regard to the impact of alcohol consumption on task-related effects, the following significant differences between morning and evening experimentation force the rejection of the null hypothesis.

Visual perception: Decreased temperature.

Cognition: Decreased temperature.

Sensory-motor output: Decreased heart rate variability (RMSSD and High Frequency Power), Increased Low Frequency Power heart rate variability and increased heart rate frequency.

With regard to the impact of alcohol consumption on differentially-related effects, the following significant differences observed for simple and complex task performance between morning and evening experimentation force the rejection of the null hypothesis for the following variables.

Cognition: Increased heart rate frequency.

Sensory-motor output: Decreased heart rate variability (Low Frequency Power).

c) This hypothesis states that the oculomotor parameters measured in perceptual, cognitive and sensory-motor tasks will be equal for both morning and evening conditions.

With regard to the impact of alcohol consumption on differentially-related effects, the following significant differences observed for simple and complex task performance between morning and evening experimentation force the rejection of the null hypothesis for the following variables.

Visual Perception: Decreased pupil size, saccade speed and saccade amplitude.

CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

The relationship between alcohol consumption and information processing impairment is still poorly understood. This aim of this study was to determine how alcohol consumption affects human information processing performance. More specifically, this study looks to determine how attentional resources are allocated while under the influence of alcohol; allowing the researcher to ascertain whether the effects of acute alcohol consumption are isolated to one specific stage in information processing or if information processing is affected in its entirety. Further aims are to identify the effects of prior caffeine consumption on this relationship and particularly to determine if caffeine has the ability to antagonise the debilitating effects of alcohol consumption. These experimental responses were compared at two varying times of the day (morning and evening) and between genders to determine if these variables confounded the results.

SUMMARY OF PROCEDURES

The current investigation assessed performance, physiological and oculomotor measures in order to obtain a holistic overview of alcohol‟s effects on information processing. The protocol consisted of six, short-duration resource- specific tasks designed to measure information processing across the three main resource stages - perception, cognition and motor output. These tasks were performed at two complexities, simple and complex, with the difference between these two complexities identifying the utilisation of the resources within a specific stage. Moreover, the average between these complexities identifies the general effects of alcohol on each stage of the information processing chain. The six tests at the two complexities comprised the test battery, with total test duration of 20 minutes. The test battery was performed four times with test batteries being separated by a 25 minute interval; total time for experimentation approximating 2 h 45 min. Three groups were utilised: The *control* group performed all test batteries under no influence. The *alcohol* group performed test batteries one and two sober, and three and four while under the influence of a 4 g/kg dose of

alcohol. The *caffeine+alcohol* group conducted test battery one sober, two under the effect of caffeine (4 mg/kg), and three and four under the influence of both caffeine and alcohol (4 g/kg). The third test battery demonstrated the effects of alcohol during the inclining phase of the blood alcohol curve, with the fourth test battery demonstrating the declining phase. Each group comprised 36 participants spilt evenly between genders. These test batteries were conducted in two experimental sessions at varying times of day: morning (10:00 – 12: 45 and 10:30 and 13:15) and evening (19:00 -21:30 and 19:30 and 22:00).

Test battery one was used to record baseline measures for performance, physiological and oculomotor parameters. This allowed for the subsequent test batteries to be compared and for data to be normalised to this initial round of testing. Breath alcohol concentrations were analysed at 20- minute intervals post alcohol ingestion until the final test battery was completed.

SUMMARY OF RESULTS

Acute alcohol consumption at a dose of approximately 0.4 g/kg body weight, effected/produced an average peak breath alcohol concentration of 0.062 % and 0.059 % for the *alcohol* and *caffeine+alcohol* groups respectively. Peak breath alcohol concentration was recorded approximately 30 to 45 minutes post alcohol ingestion for both experimental groups. Breath alcohol concentrations were higher during morning experimentation and for females when comparisons between time of day and gender were made.

Task-related results demonstrated that acute alcohol consumption significantly affected visual perception and motor performance, but little impairment was observed in the physiological and oculomotor parameters measured. All three visual perception tasks showed significant decrements in performance due to alcohol consumption, while motor performance demonstrated impairment only in the stimulus response task. Caffeine consumption showed limited impact on task-related performance, showing only one improvement in performance: a reduction in the number of errors missed during reading. The physiological parameters demonstrated greater changes during the motor tasks than the visual perception and cognition tasks. Alcohol imposed depression of heart rate frequency and heart rate variability, implying increased arousal and cognitive effort. The combination of caffeine and alcohol

however, elicited stimulating effects on the physiological parameters measured, increasing heart rate frequency and the variability between heart beats. The oculomotor measures in response to alcohol consumption demonstrated a significant decrease in saccade amplitude only; this was observed in the memory task.

Comparisons between simple and complex trials of each task showed acute alcohol consumption to have no significant effect on the performance parameters measured. However, a larger impact on the physiological and oculomotor parameters was demonstrated. Complex trials post alcohol consumption elicited greater decrements in performance and larger changes in physiological and oculomotoric function when compared against simple trials. Statistical analysis of the differences between simple and complex trials (indicators of resource utilisation) demonstrated no significance, suggesting/ indicating/ implying that the stage- specific resources were not depleted due to alcohol ingestion. The central and motor stages of human information processing showed greater sensitivity to the acute effects of alcohol consumption as compared to the perceptual stage. Caffeine consumption prior to alcohol consumption again, demonstrated little antagonising effect on alcohol impairment. No antagonism of alcohol-related performance parameters was demonstrated. Physiological measures showed that caffeine consumption imposed stimulating effects only in the neural reflex and memory tasks, increasing heart rate frequency and heart rate variability. Alcohol consumption elicited a significant decrease in saccade amplitude in the memory task, with no significant changes to oculomotor parameters imposed by caffeine.

The time of day at which alcohol was consumed had significant implications on all parameters measured. The morning experimental sessions showed higher blood alcohol concentrations, larger decrements in performance and greater changes in physiological and oculomotoric variables, compared to evening experimentation.

Comparisons between male and female performance demonstrated that female participants showed higher sensitivity to the acute impairing effects of alcohol consumption. Females showed increased sensitivity to alcohol consumption for task-related measures of reaction time (visual perception) and response duration (cognition). Simple vs. complex analysis demonstrated that males showed significantly higher recall ability but slower response

duration (cognition) when compared to female participants. Female physiological and oculomotoric function on average showed larger changes than those observed in male participants.

CONCLUSIONS

Alcohol consumption proved to induce significant impairments in task-related performance measures. These impairments were spread across all three information processing stages with the greatest impairment noted within early stage information processing (visual perception). Differences between task complexities yielded no significant performance impairment, indicating that alcohol impairment cannot be isolated to a single resource or a specific stage in the information processing.

Task-related physiological and oculomotor performance demonstrated few significant effects, indicating that the performance parameters were more sensitive to the impairing effects of alcohol consumption than were the physiological and oculomotor parameters. Conversely, alcohol consumption induced significant physiological and oculomotor variations between simple and complex tasks. It was demonstrated that alcohol consumption showed greater changes in physiology and eye movements when task complexity was high compared to simple task execution. Physiological and oculomotor variations were more prominent in the cognitive and motor stages of information processing. The mechanism used to explain the changes observed in physiological and oculomotor parameters with a lack of performance decrements, was Robert & Hockey"s compensatory control model. It was concluded that alcohol consumption increased the participants" investment of effort within tasks consequently allowing for the maintenance of performance.

Caffeine consumption prior to alcohol consumption indicated limited antagonistic effect for alcohol impairment. Unlike previous studies, this investigation showed caffeine to antagonise only a single task-related performance variable, showing that caffeine holds no antagonistic power over alcohol impairment at the current dosage. Furthermore, caffeine consumption demonstrated no antagonism for either simple or complex task performance.

The time of day at which alcohol is consumed has significant performance implications, with greater decrements observed during morning consumption. The effect of gender too has significant performance implications, with female participants experiencing greater impairments than males.

In general the results support the theory that at low to moderate blood alcohol concentrations humans can compensate for the impact of alcohol on performance by adapting focus (effort). However, with higher doses of alcohol this compensation may fail and only then performance decrements or breakdowns in performance may be evidenced.

RECOMMENDATIONS

Future investigations into the effects of acute alcohol consumption on information processing and the antagonistic properties of caffeine consumption on this system should consider the following recommendations for the methodologies employed:

The sample utilised in this study and the non-repeated design was of adequate size and suited the purpose of this investigation. However, the use of a repeated measures study may reduce the amount of group variability within breath alcohol concentrations and task performance, perhaps increasing the statistical significance observed in this investigation. Furthermore, more rigorous screening and recruitment processes should be employed to increase the homogeneity of the groups employed in a study such as this.

A more stringent control of participant requirements may ensure the reduction of variability observed between participants. Therefore, it is suggested that future studies conduct experimentation in a sleep laboratory. This will ensure participants experience similar sleep loads and patterns, eat the same type, quantity and composition of food and are subjected to exactly the same pre-test environment. Further, this setting will reduce the circadian variability between participants, resulting in more reliable data with less variability in responses. Moreover, the control of food composition and consumption will reduce the variability in dosage adjusted alcohol administration and may provide more accurate representations of performance.

Alcohol administration should be based on a more reliable method. The Widmark equation has been shown to under-predict blood alcohol concentration, therefore future investigations should study this equation and determine where the source of the under-prediction lies. This will allow for more accurate dose- adjusted alcohol administration to participants and less variability within results. Further, this would allow for a more even dose profile between males and females hence effecting comparable results between sexes.

Future studies should look to conduct extensive pilot testing with regard to alcohol dosage between participants. This pilot would allow for the researchers to determine the following pertinent factors, with regard to alcohol consumption: the dose required to effect the intended breath alcohol concentration; time to peak alcohol concentration; rate of absorption and rate of elimination. These factors will contribute to a homogeneous impairment by alcohol concentration.

Future studies should employ a more rigorous analysis of data, for example, analysis of variance for entire test battery durations as well as for the entirety of task durations (simple and complex). The implementation of interval-based analysis of variance, utilised in this study, may have shortened the task intervals to too great an extent, therefore future studies should either implement the above recommendation or increase the individual test durations. This may allow for a longer sampling time between simple and complex tasks and may produce lower variability with variables (especially those that are easily subjected to external influences, e.g. heart rate and heart rate variability). This recommendation was however beyond the scope of this investigation.

Future investigations should look to test the effects of motivation during task performance. Investigating motivation could provide interesting observations seeking to determine if well-motivated participants demonstrate reduced performance impairment from alcohol. It is hypothesised that an increase in motivation may increase the investment of effort within tasks, thereby decreasing performance decrements or perhaps allowing the subject to maintain performance.

Based on the current results, it is not recommend that caffeine be used to deter the effects of alcohol consumption, nor should it be used in conjunction with alcohol as this shows a

tendency to reduce total information processing performance. Future investigations should look to utilise a dose of caffeine that is higher than the dose administered here. This increase in dose may alter the current picture of the relationship between alcohol impairment and caffeine antagonism.

It is recommended that alcohol consumption at the current dosage (0.4 g/kg) be implemented in prolonged driving simulated studies. This is said as alcohol consumption at these breath alcohol concentrations does not seem to affect driving-related behaviour and performance. Longer duration driving and the increased cognitive effort required to sustain driving performance, may however show that driving ability is impaired by alcohol consumption at a dose of approximately 0.4 g/ kg body weight.

PRACTICAL APPLICATION

The current thesis proposes the following practical applications.

Based on the current results it appears that at a dose of 0.4 g/kg, alcohol consumption does not effect significant driving-related performance decrements. Therefore, it is suggested that when government revise the limit for drunken driving, scientific studies (such as the present study) should be considered. Although the current study implemented a simplistic driving simulated task, there is no evidence to suggest that alcohol consumption at the experimental breath alcohol concentrations impairs driving-related performance. However, future studies should focus on a prolonged driving period to gain insight into cognitive effort and effort regulation during sustained driving while intoxicated.

Individuals should avoid drinking at company functions or at client lunches that require them to return to work thereafter. As evidenced by the current investigation, the consumption of alcohol in the morning-to-mid-morning period results in greater performance decrements than evening consumption. Therefore, if the individual has to return to a working environment, the accompanying performance will be poor and the chances of work-related accidents will increase. These scenarios should be avoided and employers should be aware of the dangers inherent in relatively moderate alcohol consumption.

The current results show that caffeine has the ability to improve performance in some tasks but also shows, in the majority of tasks, a tendency to exacerbate the effects of alcohol. While individuals looking to „sober up" could benefit from caffeine consumption, this should not be seen as a remedy for alcohol intoxication. The main finding from this investigation states that caffeine in conjunction with alcohol consumption frequently has detrimental performance effects. Furthermore, compiling drinks that combine caffeine and alcohol (e.g. vodka and Red Bull ™) should be avoided in all drinking scenarios.

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APPENDICES

APPENDIX A: GENERAL INFORMATION

Experimental Schedule

Letter of information to subjects

Letter of informed consent

Drink familiarity and tolerance questionnaire

Self-assessment Morningness-eveningness questionnaire

Caffeine ingestion profile

APPENDIX B: DATA COLLECTION

Pre-test instructions

Demographic and anthropometric data collection forms

APPENDIX C: OTHER INFORMATION

Permutation table

Alcohol administration tables (Widmark calculations)

Statistical tables

APPENDIX A: GENERAL INFORMATION

Experimental Schedule

Pre-test

- Ensure computers are on software is functional
    - Drive simulator (steering wheel and software)
    - Memory task
    - Stimulus response task
    - Touchscreen (software functional)
    - Visual detection task
    - Accommodation task (Projector, distances and blocking of screen)
- Ensure all equipment is available for use
    - Data Logger
    - Eye Tracker
    - Polar HR monitor
    - Temperature sensors
    - Projector
    - Steering wheel

Habituation/introductory session

- Welcome and introduction (introduce assistants and relevant people).
- Attach HR monitor (water).
- Explanation of all testing equipment
- Seat subject.
- Issue letter of information and allow time to read.
- Verbal introduction to:
    - Research
    - Experimental conditions
    - Equipment.
- Questions.
- Participant informed consent.

- Record reference HR value.
- Demographic and anthropometric measures.
    - Stature
    - Mass
- Drink familiarity and tolerance questionnaire
- Caffeine ingestion profile
- Circadian rhythm profile
- Test battery habituation
    - Reading (60DPI and 300DPI
    - Memory (ST and LT)
    - Visual Detection (Small and large visual field)
    - Accommodation (Near and Far)
    - Fitts
    - Driving Simulator (High and Low sensitivity)

Test-session 1 (Conditions 1 and 3)

Pre arrival

- Ensure computers are on software is functional
    - Drive simulator
    - Memory task
    - Stimulus response task
    - Touchscreen
    - Visual detection task
    - Accommodation task
- Ensure all equipment is available for use
    - Data Logger
    - Eye Tracker
    - Polar HR monitor
    - Temperature sensors
    - Projector

- Steering wheel

Arrival

- Welcome and thanks.
- Assign condition sequence
- Attach HR monitor telemetry strap (water needed).
- Re-inform participant of test conditions, and conditions to be completed in this session
- Eye tracker fitment and calibration
- Data logger setup.
  - Attach temperature sensors to forehead and ear
- Start baseline test 1: (0.0 % BrAC and 0 mg/kg caffeine)
  - BrAC: Breathalyser
  - Tests 1 – 6 (Start data logger and eye tracker)
    - Performance measures: RT, TD, correct identification of stimuli (%), error rate, reading speed (words per minute), lane tracking and mean deviation.
    - Physiological measures: HR, HRV, BT, EMG (Data logger) SS, SA, PD, FB, FD (eye tracker).
- Administration of alcohol
  - Baseline test 2: 0.0 % BrAC
    - Repeat procedure as stated in baseline test 1
- Test battery at 0.05 % BrAC
  - Tests 1 – 6 (Start data logger and eye tracker)
- Test battery at 0.075 % BrAC
  - Tests 1 – 6 (Start data logger and eye tracker)
- End of testing:
  - Detain subject until BrAC = 0.03 %

Test-session 1 (Conditions 2 and 4)

Pre arrival

- Ensure computers are on software is functional
    - Drive simulator
    - Memory task
    - Stimulus response task
    - Touchscreen
    - Visual detection task
    - Accommodation task
- Ensure all equipment is available for use
    - Data Logger
    - Eye Tracker
    - Polar HR monitor
    - Temperature sensors
    - Projector
    - Steering wheel

Arrival

- Welcome and thanks.
- Assign condition sequence
- Attach HR monitor telemetry strap (water needed).
- Re-inform participant of test conditions, and conditions to be completed in this session
- Eye tracker fitment and calibration
- Data logger setup.
    - Attach temperature sensors to forehead and ear
- Start baseline test 1: (0.0 % BrAC and 0 mg/kg caffeine)
    - BrAC: Breathalyser
    - Tests 1 – 6 (Start data logger and eye tracker)
        - Performance measures: RT, TD, correct identification of stimuli (%), error rate, reading speed (words per minute), lane tracking and mean deviation.

        - Physiological measures: HR, HRV, BT, EMG (Data logger) SS, SA, PD, FB, FD (eye tracker).

- Administration of caffeine
    - Baseline test 2: 0.0 % BrAC and 4 mg/kg
        - Repeat procedure as stated in baseline test 1

- Administration of alcohol
- Test battery at 0.05 % BrAC and 4 mg/kg
    - Tests 1 – 6 (Start data logger and eye tracker)
- Test battery at 0.075 % BrAC and 4 mg/kg
    - Tests 1 – 6 (Start data logger and eye tracker)
- End of testing:
    - Detain participant until BrAC = 0.03 %

<u>Test-session 2</u>

- Repeat of test session 1; however the remainder of the experimental conditions is to be implemented.
- Carry out conditions according to permutation

Letter of information to subject

To whom it may concern

Thank you for participating as a participant in my Masters project entitled, “Effect of low and moderate alcohol consumption on different types of human performance”, your time and effort is much appreciated and is invaluable to me as a researcher.

The aim of this study is to determine how alcohol affects the various resources of the human information processing system. This study aims to investigate the alcohol-caffeine interaction, to ascertain if caffeine can deter the debilitating effects of alcohol at these breath-alcohol concentrations (BrAC). There is great practical value in ascertaining whether and to what extent alcohol has a deleterious effect on cognitive processing in work–related tasks. Further, the investigation of day versus night alcohol ingestion will provide information into the circadian effects of alcohol ingestion.

PROCEDURES

You will be required to attend one habituation and two experimental sessions. In the habituation session (your first session) an explanation of the testing procedure and what the study aims to achieve will be given to you. You should note that your participation is voluntary and if at any stage you feel you do not want to continue the experiment, you may stop. After the aims have been explained you will be requested to sign an informed consent form – giving me permission to use you as a participant and the data I record from you, in my results. Following this, age, stature (height), body mass and resting heart rate will be recorded – this session should be no longer than 30 minutes. Lastly you will be required to complete a baseline test of each dependent test in a simple and complex condition. The remaining sessions involve the actual testing protocol.

The experimental protocol requires you to attend two testing sessions, wherein you will complete two of the six experimental conditions. Each session will be no longer than two hours and will vary according to alcohol ingestion and caffeine ingestion. The dose of alcohol will be administered according to scientific equations based body weight and body water. The alcohol administered will be that of Vodka (40% volume) mixed with water. Conversely caffeine will be administered in capsule form and too will be based on body weight and your current caffeine ingestion habits.

During testing a rest interval will be implemented between each dependent test – allowing for a change over between tasks, making total test time for each session – including equipment fitment and testing - approximately 2 hours. One of these conditions will be conducted in the morning (10:30 am) and will vary according to the presence of a stimulant (i.e. one with caffeine and another without caffeine). During these testing sessions, dependent tests will be

conducted at a baseline level and at 0.0, 0.05 and 0.075 mg/100 ml breath-alcohol concentration (BrAC) respectively. Upon completion of the testing, you will be required to wait in my custody until your BrAC reaches 0.03 mg/100 ml – this is for your own safety and ethical reasons.

The other condition will be conducted in exactly the same fashion as previously stated; however, it will be conducted in the evening (20:00) in order to test for a circadian effect

All testing (except for one task) is computer based, and will require rather simple interaction with computers. You will be required to complete six dependant tests – five computer based and one reading based task. The five computer based tasks include, a visual detection task, accommodation task, memory-recall task, driving simulator task and a stimulus response task. In these tasks you will be required to respond to a number of stimuli, either by touch, the click of a button, input via the numeric keypad or by the manipulation of a steering wheel.

These dependent tests will include a battery of tests for analysing the effects of alcohol consumption on perceptual and cognitive output, as well as motor output. Perceptual and cognitive effects will analysed using the following battery of tests: two visual perception tasks [measuring; accommodation and fixation, heart rate variability and error rate], a reading task [measuring; reading speed, percentage of correct identification of stimuli, heart rate variability , reaction time error rate] and a memory/pattern recognition task [measuring; heart rate variability, reaction time error rate]. With regards to motor output the following test battery will be applied: a modified stimulus response task for motor pattern recruitment [measuring; electromyography, heart rate variability, reaction time error rate], and a neural reflex task using a driving simulator [measuring; electromyography, lane tracking, mean deviation].

Upon completion of the experimentation and interpretation, I will willingly discuss the results of my project with you, thereby sharing the knowledge gained with you, the participant.

Please note that any information obtained in both sessions will be kept confidential and at no stage or time will any of your personal information be used or publicised. The data that will be collected during the testing protocol will be used only for statistical analysis. All data that is recorded will be given a unique code, negating the use of names and ensuring anonymity. This data will be kept for a period of five years, thereafter it will be discarded. Moreover one copy of the data will be kept in the Human Kinetics and Ergonomics department and may be used for teaching or research purposes, however anonymity is still insured.

If at any time that you feel you cannot continue with the protocol, please feel free to withdraw from the protocol. Furthermore should you feel you cannot continue with the study, you may by all means withdraw at any time, this will not result in you being questioned for any reason. If there are any queries that you may have, feel free to contact me in the Human Kinetics and Ergonomics department. Further, should you feel that you have been mistreated in any way,

please feel free to contact a neutral party at the Department of Human Kinetics and Ergonomics on the details below. I would like to thank you for your participation in my masters research, your help as a participant is greatly appreciated.

Yours sincerely

David Goble

(MSc student – Department of Human Kinetics and Ergonomics)

072 225 6909

g07g2728@campus.ru.ac.za

Departmental details

Tel: (046) 603 8471

Fax: (046) 603 8934

Email: jmcdougall@ru.ac.za (secretary)

Letter of informed consent

I, …… have been fully informed of the research project entitled:

EFFECT OF LOW AND MODERATE ALCOHOL CONSUMPTION ON DIFFERENT TYPES OF HUMAN PERFORMANCE.

I have read the information sheet and understand the testing procedure that will take place. I have been told about the risks as well as benefits involved, as well as what will be expected of me as a subject. I understand that all information gained from this project will be treated confidentially, that I will remain anonymous at all times and that data obtained may be used and published for statistical or scientific purposes. All testing procedures, associated risks and the benefits from partaking in this study have been verbally explained to me as well in writing. Furthermore I understand that I may withdraw from the study at any stage, and will not be questioned as to why my withdrawal took place. I have had ample opportunity to ask questions and to clarify any concerns or misunderstandings. I am satisfied that these have been answered satisfactorily.

In light of this, and in agreeing to participate in this study, I accept joint responsibility together with the Human Kinetics and Ergonomics Department, in that should any accident or injury occur as a direct result of the protocols being performed during the study, the Human Kinetics and Ergonomics Department will be liable for any costs with may ensure and will reimburse the participant to the full amount. I.e. doctor‟s consultation, medication etc. The department will, however, waiver any legal recourse against the researchers of Rhodes University, from any and all claims resulting from personal injuries sustained whilst partaking in the investigation due negligence on the part of the participant or from injuries not directly related to the study itself. This waiver shall be binding upon my heirs and personal representatives.

I have read and understood the above information, as well as the information provided in the letter accompanying this form.

I therefore consent to voluntarily participate in this research project.

_____	_____	_____
(Print name)	(Signed)	(Date)

PARTICIPANT (OR LEGAL REPRESENTATIVE):

_____	_____	_____
(Print name)	(Signed)	(Date)

PERSON ADMINISTERING INFORMED CONSENT:

_____	_____	_____
(Print name)	(Signed)	(Date)

WITNESS 1:

_____	_____	_____
(Print name)	(Signed)	(Date)

WITNESS 2:

_____	_____	_____
(Print name)	(Signed)	(Date)

Drinking familiarity and tolerance questionnaire

Questions	0	1	2	3	4	Your score
1. How often do you have one drink containing alcohol?	1 drink every 2 months	Monthly or less	2-4 times a month	2-3 times a week	4 or more times a week	
2. In a typical 7 Day week, how many days do you have more than one alcoholic beverage	1 Day	2 Days	3-4 Days	5 Days	Every Day	
3. How many drinks containing alcohol do you have on a typical day/ night when you are drinking?	1 or 2	3 or 4	5 or 6	7 to 9	10 or more	
4. How often do you have four or more drinks on one occasion?	Hardly ever	Less than monthly	Monthly	Weekly	Daily or almost daily	
5. How often have you experienced the deleterious effects that alcohol imposes on the body?	Never	Less than monthly	Monthly	Weekly	Daily or almost daily	
6. How would you describe your tolerance to alcohol?	No tolerance	Little tolerance	Average Tolerance	Substantial tolerance	High tolerance	
7. How would you classify your drinking?	Minimal	Light	Moderate	Substantial	Heavy	
8. Do you classify yourself as a regular drinker?	No	Monthly or less	Yes: 2-4 times a month	Yes: 2-3 times a week	Yes: 4 or more times a week	
9. How often during the last year have you been unable to remember what happened the night before because you had been drinking?	Never	Less than monthly	Monthly	Weekly	Daily or almost daily	
10. Have you ever drunk Vodka before? Circle the appropriate Answer	I drink vodka all the time	I drink Vodka most nights	I drink Vodka occasionally	I have only had vodka once before	I have never drunk Vodka before	
Total (/40)						

Self-assessment Morningness-eveningness questionnaire

(Adapted from Horne and Ostberg, 1976) **(Values in red for scoring, not shown to participants)**

Participant: Date:

For each question, please select the answer that best describes you by circling the point that best indicates how you have felt in recent weeks.

1. ***Approximately* what time would you get up if you were entirely free to plan your day?**
    1. 5:00 AM – 6:30 AM 5
    2. 6:30 AM – 7:45 AM 4
    3. 7:45 AM – 9:45 AM 3
    4. 9:45 AM – 11:00 AM 2
    5. 11:00 AM – 12 noon 1

2. ***Approximately* what time you go to bed if you were entirely free to plan your evening?**
    1. 8:00 PM – 9:00 PM 5
    2. 9:00 PM – 10:15 PM 4
    3. 10:15 PM – 12:30 AM 3
    4. 12:30 AM – 1:45 AM 2
    5. 1:45 AM – 3:00 AM 1

3. **If you usually have to get up at a specific time in the morning, how much do you depend on an alarm clock?**
    1. Not all at 4
    2. Slightly 3
    3. Somewhat 2
    4. Very much 1

4. **How easy do you find it to get up in the morning (when you are not awakened unexpectedly)?**
    1. Very difficult 1
    2. Somewhat difficult 2
    3. Fairly easy 3
    4. Very easy 4

5. **How alert do you feel during the first half hour after you wake up in the morning?**
    1. Not at all alert 1
    2. Slightly alert 2
    3. Fairly alert 3
    4. Very alert 4

6. **How hungry do you feel during the first half hour after you wake?**
    1. Not at all hungry 1
    2. Slight hungry 2
    3. Fairly hungry 3
    4. Very hungry 4

7. **During the first half hour after you wake up in the morning, how do you feel?**
    1. Very tired 1
    2. Fairly tired 2
    3. Fairly refreshed 3

4. Very refreshed 4

8. **If you had no commitments the next day, what time would you go to bed compared to your usual bedtime?**
   1. Seldom or never later 1
   2. Less than 1 hour later 2
   3. 1-2 hours later 3
   4. More than 2 hours later 4

9. **You have decided to do physical exercise. A friend suggests that you do this for one hour twice a week, and the best time for him is between 7-8 AM. Bearing in mind nothing but your own internal „clock", how do you think you would perform?**
   1. Would be in good form 4
   2. Would be in reasonable form 3
   3. Would find it difficult 2
   4. Would find it very difficult 1

10. **At *approximately* what time in the evening do you feel tired, and, as a result, in need of sleep?**
   1. 8:00 PM -9:00 PM 5
   2. 9:00PM – 10:15 PM 4
   3. 10:15 PM – 12:45 PM 3
   4. 12:45 PM – 2:00AM 2
   5. 2:00 AM – 3:00 AM 1

11. **You want to be at your peak performance for a test that you know is going to be mentally exhausting and will last two hours. You are entirety free to plan your day. Considering only your „internal clock", which one of the four testing times would you choose?**
   1. 8 AM – 10 AM 6
   2. 11 AM -1 PM 4
   3. 3 PM – 5 PM 2
   4. 7 PM – 9 PM 0

12. **If you got into bed at 11 PM, how tired would you be?**
   1. Not at all tired 0
   2. A little tired 1
   3. Fairly tired 3
   4. Very tired 5

13. **For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which one of the following are you most likely to do?**
   1. Will wake up at usual time, but will not fall back asleep 4
   2. Will wake up at usual time and will doze thereafter 3
   3. Will wake up at usual time, but will fall asleep again 2
   4. Will not wake up until later than usual 1

14. **One night you have to remain awake between 4-6 AM in order to carry out a night watch. You have no time commitments the next day. Which one of the alternatives would suit you best?**
   1. Would not go to bed until the watch is over 1
   2. Would take a nap before and sleep after 2
   3. Would take a good sleep before and nap after 3
   4. Would sleep only before the watch 4

15. **You have two hours of hard physical work. You are entirely free to plan your day. Considering only your internal „clock", which of the following times would you choose?**

1. 8 AM – 10AM 4
2. 11 AM - 1 PM 3
3. 3 PM – 5 PM 2
4. 7 PM – 9 PM 1

16. **You have decided to do physical exercise. A friend suggests that you do this for one hour twice a week. The best time for her is between 10 -11 PM. Bearing in mind only your internal „clock", how well do you think you would perform?**

1. Would be in good form 1
2. Would be in reasonable form 2
3. Would find it difficult 3
4. Would find it very difficult 4

17. **Suppose you can choose your own work hours. Assume that you work a five-hour day (including breaks), your job is interesting, and you are paid based on your performance. At *approximately* what time would you choose to begin?**

1. 5 hours starting between 4-8AM 5
2. 5 hours starting between 8-9 AM 4
3. 5 hours starting between 9AM – 2 PM 3
4. 5 hours starting between 2 – 5 PM 2
5. 5 hours starting between 5 PM – 4 AM 1

18. **At *approximately* what time of the day do you usually feel your best?**

1. 5 – 8 AM 5
2. 8 – 10 AM 4
3. 10 AM – 5 PM 3
4. 5 – 10 PM 2
5. 10 PM – 5 AM 1

19. **One hears about "morning types" and "evening types". Which one of these types do you consider yourself to be?**

1. Definitely a morning type 6
2. Rather more a morning type than an evening type 4
3. Rather more an evening type that a morning type 2
4. Definitely an evening type 1

Morningness - Eveningness Scale

1. Definitely morning type	70 - 83
2. Moderately morning type	56 - 69
3. Neither type	42 - 55
4. Moderately evening type	28 - 41
5. Definitely evening type	14 - 27

Caffeine ingestion profile

	Caffeine/ dose		Average number of doses/day		Average Total/day
Beverages					
Coffee (180 ml)	125 mg	x	_____	=	_____
Decaffeinated Coffee (180 ml)	5 mg	x	_____	=	_____
Espresso (30 ml)	35 mg	x	_____	=	_____
Tea (180 ml)	50 mg	x	_____	=	_____
Green Tea (180 ml)	20 mg	x	_____	=	_____
Energy Drinks (350 ml)	250 mg	x	_____	=	_____
Hot Cocoa (180 ml)	15 mg	x	_____	=	_____
Caffeinated Soft drinks (350 ml)	40-60 mg	x	_____	=	_____
Chocolate bar (55 g)	20 mg	x	_____	=	_____

TOTAL MG. CAFFEINE PER DAY _____

> 250 milligrams per day may interfere with deep sleep

APPENDIX B: DATA COLLECTION

Pre-test instructions

Please inform the researcher of any factors that you think may influence your results on the day of testing, for example if you are taking prescription medication, are asthmatic or are ill. Please note that if you are currently using over the counter medication and or any form of medication; please express what type of medication you are on, as this may affect the results. In order for my results to be as accurate as possible, I require that you follow the following instructions before completing the test.

FOR 24 HOURS PRIOR TO TESTING:

- DO NOT DRINK ALCOHOL
- DO NOT PARTICIPATE IN ANY STRENUOUS EXERCISE
- DO NOT TAKE MEDICATION (SUCH AS PAINKILLERS, ASPRIN, OVER THE COUNTER MEDICATION AND INFLUENZA TABLETS ETC).
- ATTEMPT TO GET AT LEAST 8 HOURS OF SLEEP THE NIGHT BEFORE THE TEST.

ON THE DAY OF TESTING

- EAT A SUBSTANTIAL MEAL APPROXIMATELY 2 HOURS PRIOR TO TESTING
- DO NOT EAT ANYTHING 1.5 HOURS PRIOR TO TESTING
- DO NOT DRINK ALCOHOL
- DO NOT DRINK OR EAT ANY CAFFINATED BEVERAGE OR FOOD
- ARRIVE PROMPTLY FOR YOUR SESSION

Please as far as you can, try to comply with the above instructions as this will help me greatly in my data collection. Your cooperation is much appreciated.

Demographic and anthropometric data collection form

Subject Code:		Gender:	M	F
Subject Name:		Age:		
		Mass:		
		Stature:		
		Resting HR:		

Condition:	1 M (No caffeine)	2 M (Caffeine)	3 E (No caffeine)	4 E (Caffeine)	5 M Control	6 E Control
Start Time:						
End Time:						

		Time of ingestion	NOTES
Amount of caffeine (mg):			
Amount of alcohol (ml):			

Breath-alcohol concentration (BrAC %)				
Test	Aimed	Actual BrAC	Time	NOTES
Baseline 1	0			
Test battery 1	0			
Test battery 2	0.245			
Test battery 3	0.375			

APPENDIX C: OTHER INFORMATION

Participant permutation table

Subject Permutation

Session	Condition		
1	A	B	C
2	B	C	A
3	C	A	B
4	A	C	B
5	B	A	C
6	C	B	A
7	A	B	C
8	B	C	A
9	C	A	B
10	A	C	B
11	B	A	C
12	C	B	A
13	A	B	C
14	B	C	A
15	C	A	B
16	A	C	B
17	B	A	C
18	C	B	A
19	A	B	C
20	B	C	A
21	C	A	B
22	A	C	B
23	B	A	C
24	C	B	A
25	A	B	C
26	B	C	A
27	C	A	B
28	A	C	B
29	B	A	C
30	C	B	A
31	A	B	C
32	B	C	A
33	C	A	B
34	A	C	B
35	B	A	C
36	C	B	A

KEY	
A	Alcohol Only
B	Alcohol and Caffeine
C	Control

SUBJECTS
36 Morning and 36 evening sessions
3 per session
108 Subjects
54 Male Subjects
54 Female Subjects

(Repeated for morning and evening)

Alcohol administration tables (Widmark calculations)

Male Administraion						Female A dministration							
Alcohol in grams (g)			Alcohol in millileters (ml)			Alcohol in grams (g)			Alcohol in millileters (ml)				
Weight	0.245	0.375	Weight	0.245	0.375	Weight	0.245	0.375	Weight	0.245	0.375	g/kg	ml/kg
60	16.10	24.14	60	51.00	76.50	50	10.85	16.27	50	34.38	51.56	0.40239	1.275
60.5	16.23	24.34	60.5	51.43	77.14	50.5	10.96	16.44	50.5	34.72	52.08	0.40239	1.275
61	16.36	24.55	61	51.85	77.78	51	11.07	16.60	51	35.06	52.59	0.40239	1.275
61.5	16.50	24.75	61.5	52.28	78.41	51.5	11.17	16.76	51.5	35.41	53.11	0.40239	1.275
62	16.63	24.95	62	52.70	79.05	52	11.28	16.92	52	35.75	53.63	0.40239	1.275
62.5	16.77	25.15	62.5	53.13	79.69	52.5	11.39	17.09	52.5	36.09	54.14	0.40239	1.275
63	16.90	25.35	63	53.55	80.33	53	11.50	17.25	53	36.44	54.66	0.40239	1.275
63.5	17.03	25.55	63.5	53.98	80.96	53.5	11.61	17.41	53.5	36.78	55.17	0.40239	1.275
64	17.17	25.75	64	54.40	81.60	54	11.72	17.57	54	37.13	55.69	0.40239	1.275
64.5	17.30	25.95	64.5	54.83	82.24	54.5	11.83	17.74	54.5	37.47	56.20	0.40239	1.275
65	17.44	26.16	65	55.25	82.88	55	11.93	17.90	55	37.81	56.72	0.40239	1.275
65.5	17.57	26.36	65.5	55.68	83.51	55.5	12.04	18.06	55.5	38.16	57.23	0.40239	1.275
66	17.71	26.56	66	56.10	84.15	56	12.15	18.23	56	38.50	57.75	0.40239	1.275
66.5	17.84	26.76	66.5	56.53	84.79	56.5	12.26	18.39	56.5	38.84	58.27	0.40239	1.275
67	17.97	26.96	67	56.95	85.43	57	12.37	18.55	57	39.19	58.78	0.40239	1.275
67.5	18.11	27.16	67.5	57.38	86.06	57.5	12.48	18.71	57.5	39.53	59.30	0.40239	1.275
68	18.24	27.36	68	57.80	86.70	58	12.58	18.88	58	39.88	59.81	0.40239	1.275
68.5	18.38	27.56	68.5	58.23	87.34	58.5	12.69	19.04	58.5	40.22	60.33	0.40239	1.275
69	18.51	27.76	69	58.65	87.98	59	12.80	19.20	59	40.56	60.84	0.40239	1.275
69.5	18.64	27.97	69.5	59.08	88.61	59.5	12.91	19.37	59.5	40.91	61.36	0.40239	1.275
70	18.78	28.17	70	59.50	89.25	60	13.02	19.53	60	41.25	61.88	0.40239	1.275
70.5	18.91	28.37	70.5	59.93	89.89	60.5	13.13	19.69	60.5	41.59	62.39	0.40239	1.275
71	19.05	28.57	71	60.35	90.53	61	13.24	19.85	61	41.94	62.91	0.40239	1.275
71.5	19.18	28.77	71.5	60.78	91.16	61.5	13.34	20.02	61.5	42.28	63.42	0.40239	1.275
72	19.31	28.97	72	61.20	91.80	62	13.45	20.18	62	42.63	63.94	0.40239	1.275
72.5	19.45	29.17	72.5	61.63	92.44	62.5	13.56	20.34	62.5	42.97	64.45	0.40239	1.275
73	19.58	29.37	73	62.05	93.08	63	13.67	20.50	63	43.31	64.97	0.40239	1.275
73.5	19.72	29.58	73.5	62.48	93.71	63.5	13.78	20.67	63.5	43.66	65.48	0.40239	1.275
74	19.85	29.78	74	62.90	94.35	64	13.89	20.83	64	44.00	66.00	0.40239	1.275
74.5	19.99	29.98	74.5	63.33	94.99	64.5	13.99	20.99	64.5	44.34	66.52	0.40239	1.275
75	20.12	30.18	75	63.75	95.63	65	14.10	21.16	65	44.69	67.03	0.40239	1.275
75.5	20.25	30.38	75.5	64.18	96.26	65.5	14.21	21.32	65.5	45.03	67.55	0.40239	1.275
76	20.39	30.58	76	64.60	96.90	66	14.32	21.48	66	45.38	68.06	0.40239	1.275
76.5	20.52	30.78	76.5	65.03	97.54	66.5	14.43	21.64	66.5	45.72	68.58	0.40239	1.275
77	20.66	30.98	77	65.45	98.18	67	14.54	21.81	67	46.06	69.09	0.40239	1.275
77.5	20.79	31.19	77.5	65.88	98.81	67.5	14.65	21.97	67.5	46.41	69.61	0.40239	1.275
78	20.92	31.39	78	66.30	99.45	68	14.75	22.13	68	46.75	70.13	0.40239	1.275
78.5	21.06	31.59	78.5	66.73	100.09	68.5	14.86	22.29	68.5	47.09	70.64	0.40239	1.275
79	21.19	31.79	79	67.15	100.73	69	14.97	22.46	69	47.44	71.16	0.40239	1.275
79.5	21.33	31.99	79.5	67.58	101.36	69.5	15.08	22.62	69.5	47.78	71.67	0.40239	1.275
80	21.46	32.19	80	68.00	102.00	70	15.19	22.78	70	48.13	72.19	0.40239	1.275
80.5	21.59	32.39	80.5	68.43	102.64	70.5	15.30	22.95	70.5	48.47	72.70	0.40239	1.275
81	21.73	32.59	81	68.85	103.28	71	15.41	23.11	71	48.81	73.22	0.40239	1.275
81.5	21.86	32.79	81.5	69.28	103.91	71.5	15.51	23.27	71.5	49.16	73.73	0.40239	1.275
82	22.00	33.00	82	69.70	104.55	72	15.62	23.43	72	49.50	74.25	0.40239	1.275
82.5	22.13	33.20	82.5	70.13	105.19	72.5	15.73	23.60	72.5	49.84	74.77	0.40239	1.275
83	22.27	33.40	83	70.55	105.83	73	15.84	23.76	73	50.19	75.28	0.40239	1.275
83.5	22.40	33.60	83.5	70.98	106.46	73.5	15.95	23.92	73.5	50.53	75.80	0.40239	1.275

Male Administraion						Female Administration							
Alcohol in grams (g)			Alcohol in millileters (ml)			Alcohol in grams (g)			Alcohol in millileters (ml)				
Weight	0.245	0.375	Weight	0.245	0.375	Weight	0.245	0.375	Weight	0.245	0.375		
84	22.53	33.80	84	71.40	107.10	74	16.06	24.08	74	50.88	76.31	0.40239	1.275
84.5	22.67	34.00	84.5	71.83	107.74	74.5	16.16	24.25	74.5	51.22	76.83	0.40239	1.275
85	22.80	34.20	85	72.25	108.38	75	16.27	24.41	75	51.56	77.34	0.40239	1.275
85.5	22.94	34.40	85.5	72.68	109.01	75.5	16.38	24.57	75.5	51.91	77.86	0.40239	1.275
86	23.07	34.61	86	73.10	109.65	76	16.49	24.74	76	52.25	78.38	0.40239	1.275
86.5	23.20	34.81	86.5	73.53	110.29	76.5	16.60	24.90	76.5	52.59	78.89	0.40239	1.275
87	23.34	35.01	87	73.95	110.93	77	16.71	25.06	77	52.94	79.41	0.40239	1.275
87.5	23.47	35.21	87.5	74.38	111.56	77.5	16.82	25.22	77.5	53.28	79.92	0.40239	1.275
88	23.61	35.41	88	74.80	112.20	78	16.92	25.39	78	53.63	80.44	0.40239	1.275
88.5	23.74	35.61	88.5	75.23	112.84	78.5	17.03	25.55	78.5	53.97	80.95	0.40239	1.275
89	23.88	35.81	89	75.65	113.48	79	17.14	25.71	79	54.31	81.47	0.40239	1.275
89.5	24.01	36.01	89.5	76.08	114.11	79.5	17.25	25.87	79.5	54.66	81.98	0.40239	1.275
90	24.14	36.22	90	76.50	114.75	80	17.36	26.04	80	55.00	82.50	0.40239	1.275
90.5	24.28	36.42	90.5	76.93	115.39							0.40239	1.275
91	24.41	36.62	91	77.35	116.03							0.40239	1.275
91.5	24.55	36.82	91.5	77.78	116.66							0.40239	1.275
92	24.68	37.02	92	78.20	117.30							0.40239	1.275
92.5	24.81	37.22	92.5	78.63	117.94							0.40239	1.275
93	24.95	37.42	93	79.05	118.58							0.40239	1.275
93.5	25.08	37.62	93.5	79.48	119.21							0.40239	1.275
94	25.22	37.82	94	79.90	119.85							0.40239	1.275
94.5	25.35	38.03	94.5	80.33	120.49							0.40239	1.275
95	25.48	38.23	95	80.75	121.13							0.40239	1.275
95.5	25.62	38.43	95.5	81.18	121.76							0.40239	1.275
96	25.75	38.63	96	81.60	122.40							0.40239	1.275
96.5	25.89	38.83	96.5	82.03	123.04							0.40239	1.275
97	26.02	39.03	97	82.45	123.68							0.40239	1.275
97.5	26.16	39.23	97.5	82.88	124.31							0.40239	1.275
98	26.29	39.43	98	83.30	124.95							0.40239	1.275
98.5	26.42	39.64	98.5	83.73	125.59							0.40239	1.275
99	26.56	39.84	99	84.15	126.23							0.40239	1.275
99.5	26.69	40.04	99.5	84.58	126.86							0.40239	1.275
100	26.83	40.24	100	85.00	127.50							0.40239	1.275
100.5	26.96	40.44	100.5	85.43	128.14							0.40239	1.275
101	27.09	40.64	101	85.85	128.78							0.40239	1.275
101.5	27.23	40.84	101.5	86.28	129.41							0.40239	1.275
102	27.36	41.04	102	86.70	130.05							0.40239	1.275
102.5	27.50	41.24	102.5	87.13	130.69							0.40239	1.275
103	27.63	41.45	103	87.55	131.33							0.40239	1.275
103.5	27.76	41.65	103.5	87.98	131.96							0.40239	1.275
104	27.90	41.85	104	88.40	132.60							0.40239	1.275
104.5	28.03	42.05	104.5	88.83	133.24							0.40239	1.275
105	28.17	42.25	105	89.25	133.88							0.40239	1.275
105.5	28.30	42.45	105.5	89.68	134.51							0.40239	1.275
106	28.44	42.65	106	90.10	135.15							0.40239	1.275
106.5	28.57	42.85	106.5	90.53	135.79							0.40239	1.275
107	28.70	43.06	107	90.95	136.43							0.40239	1.275
107.5	28.84	43.26	107.5	91.38	137.06							0.40239	1.275
108	28.97	43.46	108	91.80	137.70							0.40239	1.275
108.5	29.11	43.66	108.5	92.23	138.34							0.40239	1.275
109	29.24	43.86	109	92.65	138.98							0.40239	1.275
109.5	29.37	44.06	109.5	93.08	139.61							0.40239	1.275
110	29.51	44.26	110	93.50	140.25							0.40239	1.275

Statistical Tables

Due to the large number of statistical tables these data have not been included. For a full representation of the statistical result tables please see the attached CD.