The Impact of Alcohol on the Different Components of Working Memory

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Abstract

Alcohol-consumption related deficits on complex executive functions and short-term memory have been reported in the literature, usually based on group comparisons. The present research rather used a repeated measures design, assessing 21 to 35 year old male participants on the Automated Working Memory Assessment's twelve short-term and working memory subtests in the verbal and visuo-spatial domains. During the experimental assessment, a low dose of alcohol (13.6 grams) was administered, breath alcohol concentration (BAC) was measured and subjective feelings of stimulation were assessed on the Brief Biphasic Alcohol Effects Scale (B-BAES). Repeated measures analysis of (co)variance models indicated that performance improved on the working memory processing tasks, particularly in the verbal domain. This may have been related to changes in attention functions, stimulus evaluation task demands and tacit recall. On the other hand, two of the short-term memory tasks deteriorated significantly under the experimental condition, perhaps due to alcohol-related changes in stimulus representations. Partial correlation coefficients suggested that BAC was related to deficits in performance, but only if participant age was controlled for. The structure of the B-BAES was consistent with the literature, but subjective feelings of stimulation were not associated with performance changes. Shorter test-retest delays were slightly associated with improved performance, but the research data did not fully support practice effects or a mitigating influence of alcohol consumption. Based on the present findings, the specific influence of alcohol consumption on working memory could depend on methodological design, task types, memory domain and other sources of variance.

Keywords: Acute alcohol consumption, alcohol dosage, breath alcohol concentration, Working memory, Short-term memory, Automated Working Memory Assessment, Brief Biphasic Alcohol Effects Scale

Introduction

The ingestion of alcohol (ethyl alcohol) is endemic to most societies. Conservative estimates of prevalence of consumption in South Africa are between 20% for women and 50% for men (M. Schneider, Norman, Parry, Bradshaw, & Plüddemann, 2007). Furthermore, South African binge drinking levels (>5 drinks per session on frequent occasions) are amongst the highest globally, resulting in potential negative consequences such as violence, transport-related deaths, gastro-intestinal disturbance and familial challenges (Ramsoomar & Morojele, 2012; Setlalentoa, Pisa, Thekisho, Ryke, & du Loots, 2010). Physiologically, alcohol primarily affects the central nervous system due to distribution via the bloodstream following absorption by the gastro-intestinal tract (Lieber, 1992). Alcohol consumption influences motor coordination, attention, rehearsal, short-term memory storage, executive ability, working memory processing, reasoning and other cognitive processes (Pihl, Paylan, Gentes-Hawn, & Hoaken, 2003; Saults, Cowan, Sher, & Moreno, 2007; Steele & Josephs, 1990; Weissenborn & Duka, 2003). Variations in levels and signs of intoxication are dependent on the blood/breath alcohol concentration (BAC) achieved but no clear one-to-one relationship exists for behavioural or cognitive changes (Begleiter & Platz, 1972; Lieber, 1992). However, there is disagreement regarding the precise effects of alcohol on specific cognitive functions, particularly when different theoretical models of working memory, study methodologies, physiological sample characteristics, timing of consumption and dosages are employed (Montgomery, Ashmore, & Jansari, 2011; Redick et al., 2012; Saults et al., 2007; Weissenborn & Duka, 2003). The cognitive tasks used in many studies of the impact of alcohol on working memory have confounded short-term memory and working memory processes with other factors such as inhibitory control (e.g. Field, Wiers, Christiansen, Fillmore, & Verster, 2010; Finn, Justus, Mazas, & Steinmetz, 1999), attention to stimuli (e.g. Duka & Townshend, 2004) and decision making (e.g. George, Rogers & Duka, 2005; Montgomery et al., 2011). Consequentially, whilst the impact of alcohol on working memory has been broadly investigated, existing research has lacked clear theoretical grounding and specificity of psychometric versus global measurement of short-term and working memory facets (cf. Lyvers, & Maltzman, 1991; Murata, Kawashima, & Inaba, 2001; Saults et al., 2007). The theoretical grounding of the research and selected methodologies and samples is influential in producing these consistencies.

Literature Review

Working Memory

Working memory has been defined as a combination of short-term storage and manipulation of information within a limited capacity system interfacing with visual and auditory peripheral systems (Baddeley, 2003; Baddeley, 2012; Logie, 2011; Shah & Miyake, 1999) and perhaps long-term storage (Cowan, 1997, 1999). Original theories were dominated by the concepts of storage for recall (Broadbent, 1957), rehearsal (Atkinson & Shiffrin, 1971; Logie, 2012) and transfer of information (Craik & Lockhart, 1972). However, more modern models have debated the possibility of multiple, interactive systems making use of both semantic strategies and long-term storage (Ericsson & Kintsch, 1995) and the hierarchical role of attentional processes (Cowan, 1997, 1999). Although conceptualisations of working memory now encompass a variety of theoretical assumptions, the primary focus has remained temporary storage coupled with cognitive manipulation processes (Logie, 2012). In this regard, researchers such as Baddeley and Hitch (1974), Craik and Lockhart (1972), Cowan (1997, 1999) and Ericsson and Kintsch (1995) expanded theories to include more specific modular organisations, levels of processing, the concept of embedded processes and interactions with long-term memory. The Baddeley and Hitch (1974) model, in particular, gained popularity due to its modular structure and separation of components for testable hypotheses.

Baddeley and Hitch (1974) postulated a modal model based on several sources of evidence. Firstly, two-component tasks demonstrate that short-term memory may be labile while long-term memory is relatively stable. Furthermore, evidence from neurobiologically impaired patients suggested that short-term memory tasks may be impaired whilst premorbid long-term memory remains intact (Milner, Corkin, & Teuber, 1968; Shallice & Warrington, 1970). As a result, Baddeley and Hitch (1974) originally postulated two sensory-specific short-term memory systems which were subject to errors in recall or reproduction rather than errors in encoding for long-term storage (cf. Ericsson and Kintsch, 1995) and a third system as an interface between the sensory systems, recall functions and other memory components. Unlike models such as those of Cowan (1997, 1999), neither attentional activation nor long-term storage were emphasised. Baddeley and Hitch (1974, 1983), therefore, described a three component modular concept of working memory. The phonological loop and visuo-spatial sketchpad being responsible for articulatory and visuo-spatial rehearsal respectively whilst the central executive is responsible for the coordination and control of memory functions, including the division of attention formation of ‘chunks’ of information and integration of information. The modal model has found support in neuroanatomical studies (Cabeza & Nyberg, 2000; Della Salla, Gray, Baddeley, Allamano, & Wilson, 1999; Klauer & Zhao, 2004) and various working memory assessment tasks, such as general recall and visual-tracking (Baddeley, 2010). The modal nature of the model lends itself to easy assessment of working memory.

Assessment of Working Memory

Whilst short-term memory is fairly easily assessed using recall tasks, complex working memory is somewhat more challenging. Original studies of memory focused on short-term span tasks, notably serial recall of digits (e.g. Miller, 1956). Later, more complex tasks using manipulation of information were incorporated, for example, reading comprehension and recall tasks (Daneman & Carpenter, 1980). Working memory tasks progressed over time to represent multiple components such as reading spans, sequencing, comprehension, reasoning, problem solving, resistance to distractors and manipulation of complex information (Conway et al., 2005; Redick et al., 2012). Currently, a variety of valid and reliable working memory tasks exist, demonstrating sufficient collinearity between short-term and working memory without suggesting a single component (Conway et al., 2005; Oberauer, Süβ, Wilhelm, & Wittman, 2003; Unsworth & Spillers, 2010). These findings upport the Baddeley and Hitch (1974, 1983) modal model separation although reseawrchers have cautioned that various sources of extraneous variance should be considered during assessments, including semantic strategies to assist recall of words (e.g. Redick et al., 2012), long-term memory functions (e.g. Cowan, 1997; Redick et al., 2012) and general intelligence (e.g. Conway et al., 2002; Alloway & Gregory, 2013). However, some assessments, such as Alloway's (2007) Automated Working Memory Assessment (AWMA), account for some of these factors. This is achieved by the separation of the components of working memory in accordance with the Baddeley and Hitch (1974, 1983) modal model. As a result, the AWMA assesses performance for the phonological loop, visuo-spatial sketchpad and each with involvement of the central executive separately.

The Automated Working Memory Assessment (Alloway, 2007). The Automated Working Memory Assessment (AWMA) is structurally modelled on Baddeley and Hitch's (1974, 1983) model of working memory (Alloway, Gathercole, & Pickering, 2006), based on the conception of working memory as consisting of multiple components with co-ordinated activity via a central executive (Alloway, Gathercole, Kirkwood, & Elliott, 2008; Alloway, Gathercole, Willis, & Adams, 2004). These components are verbal short-term memory (Digit Recall, Word Recall and Nonword Recall), verbal working memory (Listening Recall, Backwards Digit and Counting Recall), visuo-spatial short-term memory (Dot Matrix, Mazes Memory and Block Recall) and visuo-spatial working memory (Odd-one-out, Mister X and Spatial Recall). Short-term memory is assessed via recall tasks while working memory is assessed via tasks requiring simultaneous storage, processing and recall.

The AWMA verbal short-term memory tasks are span tasks, intended to measure the functioning of the phonological loop. The Nonword Recall task, in particular, is intended to be free of language acquisition, vocabulary development and links to long-term storage (Alloway, 2007; Archibald & Gathercole, 2007; Gathercole, 2006; Santos, Bueno, & Gathercole, 2006). This structure avoid the weaknesses of tests like the Word Recall subtest, for which semantic strategies may be utilised (Richardson, 2007; Rothen, Meier, & Ward, 2012; Woods et al., 2011) and long-term retrieval may be relevant (Hulme & Maughan, 1991). The visuo-spatial short-term memory component of the AWMA focuses on Baddeley and Hitch's (1974) hypothesised visuo-spatial sketchpad using two serial recall tasks and one static spatial memorisation task. These tasks have been shown to effectively measure visuo-spatial short-term memory (Alloway et al., 2008), free of working memory functions and separable from the verbal component (Alloway et al., 2006).

Although problem solving tasks are often used for measurement of executive and integrative functions (e.g. Conway et al., 2005), the AWMA working memory tasks focus on stimulus evaluation and processing rather than complex manipulation of intertwined skills subject to a wider variety of complex influences. The separation allows measurement of the specific components of working memory and processing as opposed to complex executive function tasks requiring planning (e.g. Tower of London test) or contingency monitoring (e.g. Wisconsin Card Sorting Test) which have been popular in studies of the impact of alcohol (Lyvers & Maltzman, 1991; Lyvers & Tobias-Webb, 2010; Weissenborn & Duka, 2003).

The Impact of Alcohol on Working Memory

Alcohol affects the central nervous system (Davies, 2003). Currently, it is believed that alcohol impacts the central nervous system via neuronal changes due to disruptions in lipid bilayers, altering the ability of ions, particularly calcium, to enter neurons resulting in the inhibition of a variety of functions, including cognitive performance (Crews, 1999; Fortier et al., 2014; Ingólfsson & Andersen, 2011; Montgomery, Ashmore, & Jansari, 2011). Additionally, the disruption of key neurotransmitters, particularly gamma-aminobutyric acid type A (an inhibitory neurotransmitter also involved in muscle tone), results in inhibited cognitive performance (Crews, 1999; Davies, 2003; Oscar-Berman & Bowirrat, 2005). Therefore, the physiological effects of alcohol consumption result in changes in changes to cognitive functions, including working memory performance. Although these effects are reversible if consumption is not chronic, even low dosages may lead to sufficient deficits to result in injurious medical consequences (Eckardt et al., 1998). However, intrapersonal and physiological factors may moderate the effect of alcohol on cognition and working memory components.

Changes in the effects of alcohol consumption on cognition may be somewhat dependent on dosage. research has shown that various dosages of alcohol may result in different deficits (cf. Lechner, Day, Metrik, Leventhal, & Kahler, 2016; Hoffman, Sklar, & Nixon, 2015; Schweizer et al., 2006; Weissenborn & Duka, 2003).

Furthermore, other physiological factors such as age (Acheson, Stein, & Swartzwelder, 1998; Belleville, Peretz, & Malenfant, 1996; Salthouse, 1994; Vogel-Sprott & Barrett, 1984) and metabolic rates (Tynjälä, Kangastupa, Laatikainen, Aalto, & Niemelä, 2012) may alter the impact of alcohol on working memory performance. Nonetheless, researchers have reported changes in performance on working memory tasks, general cognitive impairments, slowed reaction times and reduced inhibition following alcohol consumption (Field et al., 2010; Lyvers & Maltzman, 1991; Montgomery et al., 2011; Saults et al., 2007; Weissenborn & Duka, 2003). However, in these studies, cognitive and working memory tasks have not focused on specific components and failed to control for methodological factors such as baseline working memory and participant characteristics (Dougherty, Marsh, Moeller, Chokshi, & Rosen, 2000; Montgomery et al., 2011).

General findings from a number of studies of alcohol on working memory specific tasks include impairments on general working memory processes, such as deficits in backward digit span tasks (Finn et al., 1999), slowed reaction times (Grattan-Miscio & Vogel-Sprott, 2005), false alarms in Go/No-Go tasks (Finn et al., 1999), planning and adaptability deficits (Lyvers & Maltzman, 1991; Montgomery et al., 2011), impaired memory recall for verbal and visual sequences, including mnemonic strategies (Saults et al., 2007), altered spatial recognition (Weissenborn & Duka, 2003) and decreased general cognitive load activation (Paulus, Tapert, Pulido, & Schuckit, 2006). Other observed deficits have pointed to alterations in cognitive flexibility, inhibitory control speed of allocation of attention, complex information processing, perseverative errors, planning deficits and reductions in the ability to suppress information or responses (e.g. Ratti et al., 2002). These executive function deficits are quite global, leading to broad conclusions. Therefore, some of the research findings have focused on underlying functions or processes potentially responsible for the deficits observed on these executive functions.

The reported deficits in task performance have been linked to underlying functions such as inhibitory control mechanisms important for response suppression following evaluation (e.g. Claus & Hendershot, 2015; Field et al., 2010; Finn et al., 1999; Cromer, Cromer, Maruff, & Snyder, 2010), resistance to distractors (e.g. Saults et al., 2007; Schweizer at al., 2006), sensory processing functions (e.g. Crawford, 1997; Fernandez-Serrano, Perez-Garcia, Rio-Valle and Verdejo-Garcia, 2010; Hoffman et al., 2015; Lechner et al., 2015) and planning (e.g. Weissenborn and Duka, 2003). However, some of these hypotheses are contentious as research has suggested that cognitive memory load, rather than impulsivity or response inhibition, may be responsible for observed deficits (Casbon et al., 2003). However, specific measurement of these underlying functions is challenging, making comparisons of research studies unfeasible. This conundrum highlights the importance of task choice in the separation of the specific components of verbal and visuo-spatial short-term and working memory in order to remove the confounding influence of each underlying process in executive function performance. In this regard, the present research paper attempts to clarify some of the incongruences in other research through the separate analyses of the AWMA subtests and careful methodological and statistical control for known covariates such as age.

Subjective Intoxication

Subjective experiences of intoxication receives brief, if any, mention in studies. Very few studies have debated the influence of subjective experiences of intoxication when examining the impact of alcohol, particularly in low doses, on short-term and working memory. Feelings of subjective stimulation following alcohol consumption have been reported, although disagreement exists as to whether these are rather the result of an expectancy (Earleywine, 1994; Leonard & Blane, 1988). Under conditions where expectancy is observed, subjective feelings of stimulation have been associated with deficits in cognitive tasks (Marczinski, Fillmore, Henges, Ramsey, & Young, 2012). However, other research has reported that subjective feelings of stimulation following alcohol consumption do not affect working memory task performance (Cromer et al., 2010). Conversely, studies have reported that subjective feelings of sedation are more important as more impulsive responding is likely (Shannon, Staniforth, McNamara, Bernosky-Smith, & Liguori, 2011). Since the present study concerned itself with both the intrapersonal sample characteristics and the acute effects of alcohol consumption on the components of working memory, subjective feelings of stimulation were considered via the Brief Biphasic Alcohol Effects Scale (Rueger & King, 2013).

The present research selected the brief version of the Biphasic Alcohol Effects Scale as an effective measure of subjective experiences of intoxication via experiences of feeling stimulated or sedated to address the lack of consideration of this factor in other studies. The full Biphasic Alcohol Effects Scale (BAES) was validated by Martin, Earleywine, Musty, Perrine and Swift (1993) and the brief version (B-BAES) reduced the number of adjectives while retaining the full version's factors (Rueger & King, 2013). The assessment outcomes mirrored the observed breath alcohol levels, behavioural markers and reported feelings of stimulation and sedation by the participants (Martin et al., 1993; Poprawa, 2015). Resultantly, the B-BAES appears to be a valid measure of subjective intoxication. Use of the B-BAES also allowed the present research to account for the association of alcohol in the stimulated versus sedated domains, as well as the impact of subjective feelings of stimulation on the components of working memory. Based on consideration of methodological factors such as baseline performance and sample characteristics, inclusion of covariates such as subjective stimulation and the use of multiple task types, the present study sought to assess the effect of a low dose of alcohol on a variety of components of short-term and working memory.

Methods

Instruments

The Automated Working Memory Assessment. The Automated Working Memory Assessment (AWMA) comprises of twelve tests and produces four components, namely, verbal short-term memory (Digit Recall, Word Recall, Nonword Recall), visuo-spatial short-term memory (Dot Matrix, Block Recall, Mazes Memory), verbal working memory (Listening Recall, Backwards Digit, Counting Recall) and visuo-spatial working memory (Odd-one-out, Mister X, Spatial Recall) (Alloway, 2007; Alloway et al., 2006). These components encompass the phonological loop and visuo-spatial sketchpad, as well as each in relation to central executive functions according to the Baddeley and Hitch (1974, 1983) modal model of working memory. Table 1 describes the activities required by the AWMA subtests.

Table 1

Subsets and brief descriptions of the Automated Working Memory Assessment's components

Component	*Test*	*Description*
Verbal Short-term Memory	Digit Recall	Auditory presentation of a sequence of digits requiring recall in the correct order
	Word Recall	A sequence of words is heard and the individual attempts to recall each sequence in the correct order
	Nonword recall	The individual hears a sequence of nonsense words (nonwords) and attempts to recall each sequence in the correct order
Visuo-spatial Short-term Memory	Dot Matrix	The individual is shown the position of a red dot in a series of four by four matrices. Recall is demonstrated by tapping the square where the dot appeared
	Mazes Memory	The participant views a maze with a red path drawn through it then attempts to trace the same path on a blank maze
	Block Recall	A series of blocks being tapped are viewed and the sequence should be reproduced in the correct order by selecting on an image of the blocks
Verbal Working Memory	Listening Recall	A series of sentences are heard and judged to be true or false. At the end of the trial the individual attempts to recall the final word of each sentence in the presented order
	Counting Recall	The number of red circles in an array is counted then the tallies over several trials are recalled in the correct order
	Backwards Digit Recall	A sequence of digits is heard and should be recalled in a backwards order
Visuo-spatial Working Memory	Odd-One-Out	Three shapes are presented in a row and the individual must identify the Odd-One-Out. At the end of each trial the individual recalls the location of the odd shape out
	Mister X	A picture of two Mister X figures is viewed and the individual must identify whether the Mister X with the blue hat is holding the ball in the same hand as the Mister X with the yellow hat (blue hat Mister X may be rotated). At the end of each trial the individual attempts to recall the locations in the correct order based on markings of six possible positions
	Spatial Recall	The individual views two shapes where the shape on the right has a red dot and then identifies whether the shape (which may be rotated) is the same or opposite (mirror image) to the one on the left. At the end of each trial the individual should recall the location of each red dot in the correct order from three possible positions.

Alloway et al. (2006) explored the temporal reliability of the AWMA with a sample of approximately 700 school children and reported variable Pearson's *r* values fluctuating around $r = .800$, comparable to studies using adults with other assessments of working memory and intelligence (cf. Lo, Humphreys, Byrne, & Pachana, 2012). The AWMA demonstrated convergent validity when correlated with scores on the Wechsler Intelligence Scales for Children IV (WISC-IV) Working Memory Index (WMI) (Alloway et al., 2008). Holmes et al. (2010) also reported comparable levels of categorisation of working memory function in diagnosing children with attention deficit disorders and the Delis-Kaplan Executive function System. Two adaptation studies also demonstrated internal reliability with Injoque-Ricle, Calero, Alloway and Burin (2011) and Absatova (2015) reporting Cronbach's alpha values of between $\alpha_{Cr} = .61$ and $\alpha_{Cr} = .92$ for Spanish and Russian children respectively. Engel, Santos and Gathercole (2008) reported that the AWMA was culture fair for a sample of Brazilian children, except for the Counting Recall subtest, while Nadler and Archibald (2014) reported similar findings to Alloway et al. (2006) for native French speaking Canadian children.

The Brief Biphasic Alcohol Effects Scale (B-BAES). The present research included a measure of subjective intoxication for the purposes of understanding whether subjective stimulation influenced performance in conjunction with alcohol consumption. The Biphasic Alcohol Effects Scale was developed to assess the subjective stimulant and sedated properties of alcohol consumption (Martin et al., 1993). Cronbach's alpha values of $\alpha_{Cr} = .85$ to $\alpha_{Cr} = .94$ were obtained for the final 14 item scale along with test-retest values over two weeks of between $r = .23$ and $r = .70$ for the original 24 item scale which was later reduced to only 14 items. Further consideration of the two-component structure (confirmatory factor analysis) sub-scale produced Cronbach's alpha values of $\alpha_{Cr} = .87$ to $\alpha_{Cr} = .94$ for the sedative and stimulant scales respectively. Item-total correlations ranged between $r = .58$ and $r = .86$ with a mean value of $r = .65$ for the sedative sub-scale and $r = .81$ for the stimulant sub-scale. A shorter version of the BAES, the six item Brief Biphasic Alcohol Effects Scale (B-BAES), was validated using a sample of 104 drinkers during a laboratory study (Rueger & King, 2013). Six items, rather than fourteen, were used which were rated on a consensus scale of one to ten. The items, "Energized", "Excited", "Sedated", "Slow Thoughts", "Sluggish" and "Up", produced the same two-factor structure as found in the original BAES validations (Rueger & King, 2013).

Procedure

Ethical clearance was granted for this study from the relevant committees. All participants signed declarations of truth regarding the demographic information collected and informed consent documents. Demographic data on date of birth, home language, ethnicity, body weight, height, average exercise levels, whether the participant was involved in a labour-intensive job, average alcohol consumption per week and number of times in the prior two months more than five standard drinks had been consumed in a single session. Exclusion criteria included diagnosis of physical or mental illness, suspected alcohol or drug dependency, chronic illness, specific medications known to interact with alcohol, binge drinking based on more than five standard drinks in a single session twice within a two week period in the last two months or never consuming alcohol.

The Automated Working Memory Assessment (AWMA) was administered as per the manual for a baseline measurement followed by a minimum four-week delay (*min* = 28 days, *max* = 213 days, $M = 87.38$ days, $SD = 52.59$ days) and an experimental session during which the subtests were effectively randomised ($\chi^2 = 127.50$, $df = 121$, $p = .325$) and the experimental protocol was implemented. Prior to the experimental session participants were requested to eat a small meal approximately two hours prior to the assessment and refrain from heavy exercise, high sugar products or alcohol. Following familiarisation with the breathalyser and Brief Biphasic Alcohol Effects Scale (B-BAES), a beverage consisting of 40 millilitres Smirnoff Triple Distilled vodka containing 43% alcohol by volume combined with 200 millilitres of Schweppes Tonic Water was administered producing a total of approximately 13.6 grams, or 17.2 millilitres, of ethyl alcohol consumed within ten minutes. Following a five-minute delay to ensure the absence of residual alcohol in the mouth, the experimental protocol of BAC reading followed by B-BAES administration then AWMA subtest performance commenced. Post-test BAC and B-BAES readings were conducted. A breath alcohol reading of 0.00 was required prior to participants leaving the venue.

Data Analysis

All data was stored securely and remains confidential. The AWMA responses were recorded automatically via the software and captured. The paper and pencil responses to the B-BAES and BAC readings were captured electronically. Data analysis was conducted using SPSS® version 24. The variables were analysed descriptively and the normality of the distributions was assessed via skewness and kurtosis statistics as well as the Kolmogorov-Smirnov and Shapiro-Wilk tests, included to reduce the incidence of Type I errors should the Kolmogorov-Smirnov test have been too conservative (Howitt & Cramer, 2011; Razali & Wah, 2011; Rosenthal & Rosnow, 2008; Shapiro & Wilk, 1965). Probability levels were set at $\alpha = .05$ for statistical significance and $\alpha = .08$ for approaching statistical significance as an estimate. Effect sizes (partial eta squared) were considered per case and in context of the inferential statistics and classified as small (≤ .010), medium (±.060) and large (≥ .140) (Cohen, 1988).

Breath alcohol concentration readings were calculated as an average and the early portion of the "Stimulated" component of the B-BAES was calculated as an average. These alterations were due to the tapering off of values towards the end of the assessment and the apparent association of the "Stimulated" early values with average BAC. Pearson's *r* and Spearman's rho (ρ) correlation coefficients were calculated for the demographic and lifestyle scale variables, BAC readings and psychometric assessment results. Associations between baseline and experimental measurements on the AWMA were also calculated. Correlation coefficients between the repeated measures differences on the AWMA and participant age, test-retest delay periods, BAC averages and the B-BAES derived "Stimulated" scale were conducted. Matched pairs t-tests with bias accelerated bootstrapping (*B* = 1000) were conducted as a pre-analysis to assess the viability of the sample size for further analysis. Repeated measures analysis of (co)variance were conducted to allow each participant to act as his/her own control whilst accounting for the influence of other values, such as participant age. Therefore, between-group differences were eliminated and challenges surrounding small-sample research size were reduced (Detry & Ma, 2016; Ho, 2006; Howitt & Cramer, 2011; Huck, 2009; Littell, Henry, & Ammerman, 1998; Rosenthal & Rosnow, 2008). The interaction effects of these models were used to understand the relative importance of each control variable in relation to the test-retest differences (Hair et al., 1987; Rosenthal & Rosnow, 2008). The effect sizes of the models were carefully considered, particularly due to the small sample size (Bakeman, 2005; Fritz et al., 2012; Howitt & Cramer, 2011; Huck, 2009; Rosenthal & Rosnow, 2008). Lastly, partial and semi-partial correlation coefficients were assessed to understand differences between the two assessment sessions in context of breath alcohol concentrations.

Results

Sample

The sample comprised of sixteen males between the ages of 21.16 and 31.13 years (*M* = 25.72 years, *SD* = 3.28 years, SE_M = 0.82 years). Most of the participants were Black African (*n* = 11) whilst the remainder were White/Caucasian (*n* = 4) or Indian (*n* = 1). A variety of home languages were reported and, therefore, participants were grouped into languages of African origin (*n* = 11) and languages of European origin (*n* = 5). Body mass indices (BMI) were calculated (*M* = 22.60, *SD* = 3.19) based on weight in kilograms divided by the square of height in metres. Most of the sample were of normal weight (*n* = 13) with BMI values between 18 and 22 and the remainder were overweight (*n* = 3). Since BMI may be related to muscle mass, exercise levels were examined. Most participants reported exercising once or twice per week (*n* = 7) and equal numbers (*n* = 3) did not exercise, exercised three or four times per week or exercised more than four times per week. Most participants consumed three or four units of alcohol per week (*n* = 6) whilst the remainder consumed one or two units per week (*n* = 4) or five or six units per week (*n* = 4). Only two participants consumed seven or more units per week. Binge drinking behaviour with an extended delay period between incidences was reported by most participants (*n* = 14).

Preliminary Analyses

Age, height and body mass index (BMI) showed normal distributions and dispersions. However, participant weight significantly differed from the normal distribution (*K-S* = 0.225, *p* = .030). Table 2 shows the distribution, dispersion and normality values of the demographic variables.

Table 2

Tests of normality of demographic variables: Age, Height, Weight and Body Mass Index (n = 16)

	Range			*Dispersion*			*Normality*				*Tests of normality*			
	Min	*M*	*Max*	*Var*	*SD*	*SE*	*Skewness*	$SE_{Skewness}$	*Kurtosis*	$SE_{Kurtosis}$	*Kolmogorov-Smirnov*	*p*	*Shapiro-Wilk*	*p*
Age (Years)	21.16	25.72	31.13	10.752	3.280	0.279	0.223	0.564	-1.123	1.091	0.152	.200	0.944	.403
Height (cm)	160.00	176.38	195.00	109.717	10.475	2.619	-0.163	0.564	-0.398	1.091	0.193	.972	0.927	.218
Weight (kg)	54.00	70.56	92.00	175.862	13.261	3.315	0.631	0.564	-1.246	1.091	0.225	.030*	0.859	.018*
BMI (Points)	18.51	22.60	29.39	10.144	3.185	0.796	0.819	0.564	-0.157	1.091	0.182	.163	0.926	.207

*Significant at the 5% level

As shown in Table 2, the demographic data collected displayed a fairly wide dispersion but few abnormal statistics of normality excepting participant weights (*K-S* = 0.225, *p* = .030). Breath alcohol concentration values were not normally distributed (*K-S* = 0.241, *p* = .014), reflecting the expected peak and taper values. Figure 1 shows the expected structure of the BAC curve over the 13 reference points. The average BAC figure was used for the inferential analyses ($M = 0.013$, $SD = 0.012$, $SE_M = 0.003$).

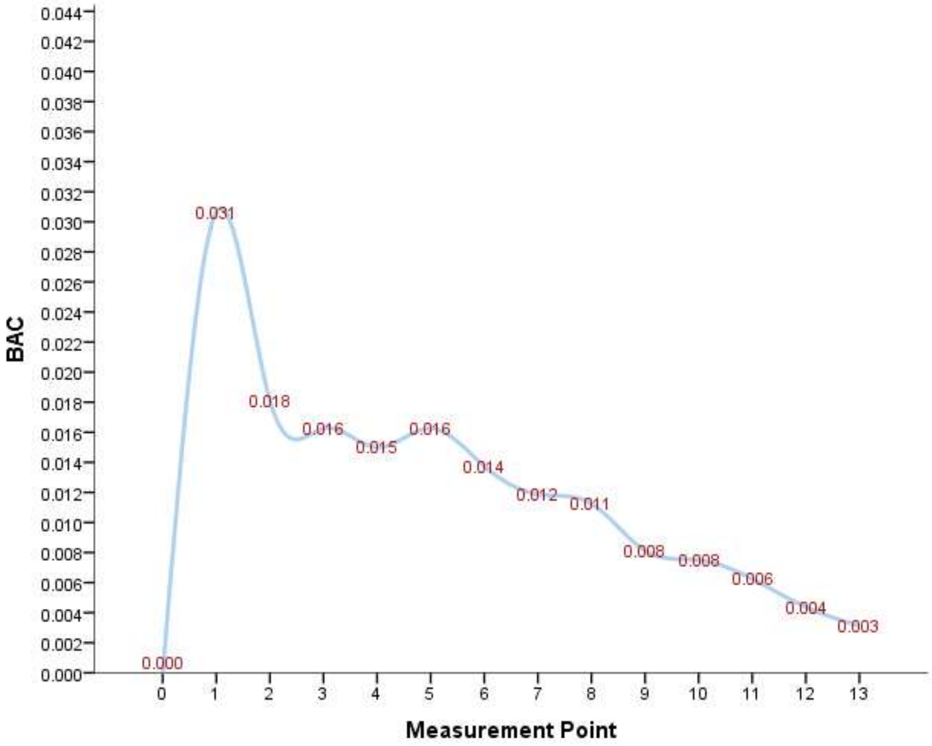

Figure 1. BAC Curve over the 13 reference points (*n* = 16)

The means of the baseline and experimental AWMA assessments fell within one standard deviation (*SD* = 15) of the mean (*M* = 100) described by the literature (Alloway, 2007). The exception was the Word Recall subtest during the baseline condition (*M* = 83.30) and experimental condition (*M* = 80.94). Table 3 shows the descriptive values for the baseline and experimental measurements of the AWMA subtests.

Table 3

Descriptive Statistics and Distribution of the Twelve AWMA Subtests (n = 16)

	Baseline Assessment					*Experimental Assessment*				
	Max	*Min*	*M*	*SE*	*SD*	*Max*	*Min*	*M*	*SE*	*SD*
Digit Recall	133	71	90.69	3.86	15.44	133	69	90.75	4.12	16.46
Word Recall	116	66	83.30	3.73	14.92	120	66	80.94	3.95	15.80
Nonword Recall	122	82	103.72	2.19	8.77	122	77	102.60	3.39	13.56
Dot Matrix	113	68	89.13	3.49	13.97	130	63	92.13	4.32	17.26
Mazes Memory	126	74	99.50	3.54	14.15	126	66	93.00	4.14	16.56
Block Recall	118	60	82.44	3.46	13.84	106	65	82.56	3.20	12.79
Listening Recall	119	73	93.38	3.68	14.74	122	80	98.50	3.14	12.58
Counting Recall	119	76	96.50	2.74	10.97	122	80	103.13	3.19	12.76
Backwards Digit	130	47	86.19	4.89	19.56	132	67	93.00	4.60	18.42
Odd-One-Out	129	74	96.75	3.72	14.86	114	79	97.69	2.47	9.88
Mister X	123	81	97.75	3.51	14.05	134	68	101.31	4.52	18.07
Spatial Recall	127	75	99.25	4.26	17.04	125	79	98.31	4.05	16.21

The values of skewness and kurtosis fell within the accepted -1.000 to +1.000 range and tests of normality were not statistically significant ($p > .050$) in most cases. A few of the subtests did deviate statistically significantly from the normal distribution. These were the baseline Digit Recall subtest ($K\text{-}S = 0.230$, $p = .023$), and Backwards Digit subtest ($K\text{-}S = 0.239$, $p = .015$) as well as the experimental assessments of Word Recall ($K\text{-}S = 0.248$, $p = .009$) and the Odd-one-out ($K\text{-}S = 0.215$, $p = .046$).

The Brief Biphasic Alcohol Effects Scale (B-BAES) was summated using the early averages of agreement with feelings of stimulated to create a derived scale, “Stimulated”, for further analysis. Higher values of “Stimulated” suggested more congruence with feelings of stimulation early in the assessment ($M = 6.579$). Table 4 demonstrates the separation of the stimulated and sedated components of the instrument based on the six items. These correlation coefficients suggested that the instrument’s structure operated appropriately for the present sample.

Table 4

Correlation Matrix of the B-BAES Mean Ratings over the Thirteen Reference Points (n = 16)

	Energised	Excited	Sedated	Slow Thoughts	Sluggish	Up
Energised	1					
Excited	.796**	1				
Sedated	.087	-.225	1			
Slow	-.410	-.559*	.565*	1		
Sluggish	-.122	-.068	-.270	-.148	1	
Up	.787**	.619*	.149	-.401	-.307	1

*Significant at the 5% level

**Significant at the 1% level

The preliminary analyses suggested that the variables showed sufficient dispersion and normality to proceed with parametric analyses. Prior to conducting further inferential analyses. The specific variables with potential for covariation over the difference scores was considered by examining the interrelationships between the variables. These analyses indicated that, except for participant age, no significant demographic differences ($p > .050$) were present for the AWMA baseline, or experimental, scores, BAC readings or the B-BAES values. Therefore, only participant age was considered further as a covariate in the inferential analyses due to its correlational relationship with average BAC readings ($r = -.581$, $p = .018$) and the derived “Stimulated” scale ($r = -.517$, $p = .050$), which was also correlated with average BAC ($r = .497$, $p = .050$).

Inferential Analyses

Preliminary Comparisons of the Repeated Measures

Descriptive differences between the baseline and experimental AWMA scores. The majority of the AWMA subtest scores increased under the experimental condition although the short-term memory subtests were quite stable. This was particularly consistent for the Verbal Working Memory scores whilst the differences were more variable for the short-term memory subtests resulting in composite score differences closer to zero. Negative values of mean difference indicate an improvement in performance whilst positive values indicate a decrease in performance based on the subtraction of the experimental values from the baseline values to calculate the difference, labelled as “baseline – experimental”. Table 5 shows the baseline, experimental and difference descriptive statistics on the AWMA subtests.

Table 5

Baseline, Experimental and Baseline Repeated Measures (Baseline – Experimental) Descriptive Statistics for the AWMA (n = 16)

	Baseline				*Experimental*				*Repeated-measures Difference*			
	M	*SD*	*Max*	*Min*	*M*	*SD*	*Max*	*Min*	*M*	*SD*	*Max*	*Min*
Digit Recall	91.00	15.00	133.00	71.00	91.00	16.00	133.00	69.00	-0.06	8.99	19.00	-14.00
Word Recall	83.30	14.90	116.00	66.00	81.00	16.00	120.00	66.00	2.36	8.30	18.90	-11.00
Nonword Recall	103.70	8.80	122.00	82.00	102.60	13.60	122.00	77.00	1.12	12.93	32.00	-18.10
Dot Matrix	89.00	14.00	113.00	68.00	92.00	17.00	130.00	63.00	-3.00	11.52	17.00	-25.00
Mazes Memory	100.00	14.00	126.00	74.00	93.00	17.00	126.00	66.00	6.50	16.39	32.00	-28.00
Block Recall	82.00	14.00	118.00	60.00	83.00	13.00	106.00	65.00	-0.13	9.08	20.00	-12.00
Listening Recall	93.00	15.00	119.00	73.00	99.00	13.00	122.00	80.00	-5.13	10.75	14.00	-21.00
Counting Recall	97.00	11.00	119.00	76.00	103.00	13.00	122.00	80.00	-6.63	11.40	13.00	-23.00
Backwards Digit	86.00	20.00	130.00	47.00	93.00	18.00	132.00	67.00	-6.81	13.71	18.00	-39.00
Odd-One-Out	97.00	15.00	129.00	74.00	98.00	10.00	114.00	79.00	-0.94	9.91	18.00	-18.00
Mister X	98.00	14.00	123.00	81.00	101.00	18.00	134.00	68.00	-3.56	11.97	13.00	-24.00
Spatial Recall	99.00	17.00	127.00	75.00	98.00	16.00	125.00	79.00	0.94	7.38	16.00	-11.00

Preliminary repeated measures analyses of (co)variance. General linear models were created for each of the subtest score differences. Due to the small sample size, confirmatory matched pairs *t*-tests were also conducted with bias corrected accelerated (BCa) bootstrapping ($B = 1000$) yielding statistics along with measures of bias. The bias values were minimal, indicating the suitability of the sample variance. Later, identified covariates are also considered and the model statistics are compared for changes. Table 6 shows the statistics for the repeated measures analysis of variance for the AWMA subtests. Effect sizes and reported power provide additional interpretive information in conjunction to the *F* statistics and probability values.

Table 6:

Repeated Measures Analysis of Variance of the AWMA Subtests (n = 16)

	Model			*Error*			*Model Statistics*			
	*SS**	*df*	*Mean Square*	*SS**	*df*	*Mean Square*	*F*	*p*	$\eta^2_{Partial}$	*Power (1-β)*
Digit Recall	0.031	1	0.031	605.469	15	40.365	0.001	.978	.000	.050
Word Recall	44.651	1	44.651	516.159	15	34.411	1.298	.273	.080	.187
Nonword Recall	10.013	1	10.013	1254.522	15	83.635	0.120	.734	.008	.062
Dot Matrix	72.000	1	72.000	995.000	15	66.333	1.085	.314	.067	.164
Mazes Memory	338.000	1	338.000	2014.000	15	134.267	2.517	.133	.144	.318
Block Recall	0.125	1	0.125	617.875	15	41.192	0.003	.957	.000	.050
Listening Recall	210.125	1	210.125	866.875	15	57.792	3.636	.076	.195	.431
Counting Recall	351.125	1	351.125	974.875	15	64.992	5.403	.035	.265	.585
Backwards Digit	371.281	1	371.281	1410.219	15	94.015	3.949	.065	.208	.460
Odd-One-Out	7.031	1	7.031	736.469	15	49.098	0.143	.710	.009	.065
Mister X	101.531	1	101.531	1073.969	15	71.598	1.418	.252	.086	.200
Spatial Recall	7.031	1	7.031	408.469	15	27.231	0.258	.619	.017	.258

*Type III Sum of Squares

As Table 6 shows, the effect size for the Mazes Memory subtest differences was large although statistical significance was not achieved ($F(1,15) = 2.517$, $p = .133$, $\eta^2_{Partial} = .144$, $1 - \beta = .318$). The Mazes Memory subtest values represented a substantial deterioration in performance during the experimental assessment session ($M_{\text{Difference}} = 6.500$, $SD_{\text{Difference}} = 16.387$, $SE_{\text{Mean}} = 4.097$). Improvements in performance in the experimental assessment for the repeated measures differences for the Listening Recall subtest scores ($M_{\text{Difference}} = -5.125$ $SD_{\text{Difference}} = 10.751$, $SE_{\text{Mean}} = 2.688$) approached statistical significance with a substantial effect size ($F(1,15) = 3.535$, $p = .076$, $\eta^2_{Partial} = .195$, $1 - \beta = .431$). The repeated measures mean differences for the Counting Recall subtest score ($M_{\text{Difference}} = -6.625$, $SD_{\text{Difference}} = 11.355$, $SE_{\text{Mean}} = 2.850$) show the improvement in performance during the experimental condition. Significant differences, with very large effect sizes, were observed between the baseline and experimental measures of Counting Recall ($F(1,15) = 5.403$, $p = .035$, $\eta^2_{Partial} = .265$, $1 - \beta = .585$). The mean experimental session value for the Backwards Digit subtest of verbal working memory was also larger than the baseline value ($M_{\text{Difference}}$ = -6.813, $SD_{\text{Difference}}$ = 13.712, SE_{Mean} = 3.428) but only approached statistical significance although the effect size was very large (F(1,15) = 3.949, p = .065, $\eta^2_{Partial}$ = .208, 1 – β = .460). Therefore, the preliminary comparisons suggested that scores on the verbal working memory subtests improved under the experimental condition with substantial effect sizes for the analysis of variance models. To fully understand these comparisons, the covariates test-retest delay, participant age and the B-BAES also had to be considered since they altered the models in many cases, even if no initial statistically significant comparison was present.

The Influence of Alcohol on the Different Components of Working Memory: Full Models Accounting for the Covariates

The initial models calculated sought to understand the changes in performance over the repeated administration of the AWMA, but the preliminary analysis also showed that average BAC and participant age (r = -.581, p = .018), average BAC and the derived "Stimulated" scale (r = .497, p = .050) and participant age and the derived "Stimulated" scale (r = -.517, p = .050) interacted as potential covariates which may have affected the outcome of the comparisons. Therefore, the covariates required further consideration and were analysed in additional to the repeated measures models as well as through partial correlation coefficients to understand the impact of "Stimulated" and participant age on the relationship between average BAC and the repeated measures differences.

Verbal Short-term Memory. The verbal short-term memory subtests did not originally differ significantly. The Digit Recall comparisons of repeated measures was negligible (F(1,15) = 0.001, p = .978, $\eta^2_{Partial}$ = .000, 1 – β = .050), but changed to a model with a larger effect size when average BAC was controlled for (F(1,14) = 1.860, p = .194, $\eta^2_{Partial}$ = .117, 1 – β = .246) and an interaction was present (F = 3.297, p = .091, $\eta^2_{Partial}$ = .191, 1 – β = .394). The interaction implied that tendencies toward deterioration in performance were associated with higher average BAC readings (r = .437, p = .091). Control for participant age resulted in a model with a very large effect size (F(1,14) = 3.814, p = .071, $\eta^2_{Partial}$ = .214, 1 – β = .444) and a large effect size of the linear interaction (F = 3.887, p = .069, $\eta^2_{Partial}$ = .217, 1 – β = .451). The correlation coefficient suggested that younger participants were more likely to show deteriorations in performance (r = -.444, p = .085). The zero-order correlation between average BAC and the repeated measures differences (r = .437, p = .091) weakened when age was controlled for (r = .230, p = .409), suggesting that age magnified the relationship observed. Although participant age influenced the comparisons, control for the "Stimulated" scale did not (F(1,14) = 0.362, p = .557, $\eta^2_{Partial}$ = .025, 1 – β = .087) and no interaction was present (F = 0.370, p = .553, $\eta^2_{Partial}$ = .026, 1 – β = .088). Furthermore, "Stimulated" was not strongly correlated to the repeated measures differences (r = .160, p = .553). Although the zero-order correlation coefficient between average BAC suggested that higher BAC levels were associated with deteriorations in performance (r = .437, p = .091) was impacted by age, "Stimulated" did not substantially affect the relationship (r = .417, p = .122).

The Word Recall subtest comparisons were not statistically significant (F(1,15) = 1.298, p = .273, $\eta^2_{Partial}$ = .080, 1 – β = .187) but control for average BAC increased the F statistic and effect size values substantially (F(1,14) = 2.718, p = .121, $\eta^2_{Partial}$ = .163, 1 – β = .336) although the linear interaction was small (F = 1.390, p = .258, $\eta^2_{Partial}$ = .080, 1 – β = .196). However, when participant age was controlled for a considerable increase in the statistical values was observed (F(1,14) = 4.834, p = .045, $\eta^2_{Partial}$ = .257, 1 – β = .535) and the interaction was statistically significant (F = 5.646, p = .032, $\eta^2_{Partial}$ = .287, 1 – β = .599). This was illustrated by the significant correlation between differences on the Word Recall subtest and participant age (r = .536, p = .032). Furthermore, the negative zero-order correlation between average BAC and differences over the repeated measures on Word Recall (r = -.301, p = .258) initially suggested that higher BAC readings were associated with improvements in performance. However, control for participant age altered this relationship to close to zero (r = .016, p = .956), suggesting an important role of this control variable. Control for "Stimulated" also resulted in a substantial increase in the model statistics (F(1,14) = 2.294, p = .152, $\eta^2_{Partial}$ = .141, 1 – β = .292) and the interaction's effect size was of medium strength (F = 1.710, p = .109, $\eta^2_{Partial}$ = .109, 1 – β = .230). Furthermore, the zero-order correlation between average BAC and differences on the Word Recall subtest (r = -.301, p = .258) tended towards a zero value when "Stimulated" was controlled for (r = -.167, p = .152). As a result, both participant age and subjective feelings of stimulation altered the relationship between average BAC readings and differences on the Word Recall repeated measures but the influence of age was considerably stronger.

The original deterioration on the Nonword Recall subtest was not statistically significant (F(1,15) = 0.120, p = .734, $\eta^2_{Partial}$ = .008, 1 – β = .062) and the model was apparently unaffected by average BAC levels (F(1,14) = 0.533, p = .478, $\eta^2_{Partial}$ = .037, 1 – β = .105) although a moderate effect size was present for this interaction (F = 1.710, p = .212, $\eta^2_{Partial}$ = .109, 1 – β = .230) due to the positive correlation coefficient (r = .330, p = .212). However, participant age did not appear to affect the Nonword Recall repeated measures differences in the same manner as for the other verbal short-term memory subtests (F(1,14) = 0.009, p = .924, $\eta^2_{Partial}$ = .001, 1 – β = .051), especially considering the negligible interaction (F = 0.003, p = .955, $\eta^2_{Partial}$ = .001, 1 – β = .050).

Furthermore, no substantial changes were noted in the partial correlation coefficient controlling for participant age (r = .394, p = .146) in comparison to the zero-order correlation coefficient between average BAC and the repeated measures differences on Nonword Recall (r = .330, p = .212). The same trend was observed when "Stimulated" was controlled for where the model statistics were not substantially altered (F(1,14) = 0.003, p = .960, $\eta^2_{Partial}$ = .000, 1 – β = .050), no substantial linear interaction was present (F = 0.000, p = .987, $\eta^2_{Partial}$ = .000, 1 – β = .050) and the partial correlation coefficient controlling for "Stimulated" (r = .378, p = .165) was very similar to the zero-order coefficient between average BAC and the Nonword Recall differences (r = .330, p = .212). Resultantly, although average BAC levels did seem to attenuate the differences on the Nonword Recall subtest to some extent, participant age and "Stimulated" did not.

Verbal Working Memory. The improvements observed on the Listening Recall subtest approached statistical significance with a very large effect size (F(1,15) = 6.636, p = .076, $\eta^2_{Partial}$ = .195, 1 – β = .431) but these statistics were reduced when average BAC was controlled for (F(1,14) = 2.436, p = .141, $\eta^2_{Partial}$ = .148, 1 – β = .307). The linear interaction suggested an absence of a relationship between average BAC and differences on the Listening Recall subtest (F = 0.180, p = .678, $\eta^2_{Partial}$ = .013, 1 – β = .068) which was confirmed by the small correlation coefficient (r = .678). Control for participant age also reduced the model statistics (F(1,14) = 1.168, p = .298, $\eta^2_{Partial}$ = .077, 1 – β = .172). Coupled with the minimal linear interaction (F = 0.732, p = .407, $\eta^2_{Partial}$ = .050, 1 – β = .126) and positively enhanced partial correlation coefficient when age was controlled for (r = .223, p = .407) in comparison to the zero-order coefficient (r = .113, p = .678), the findings suggested that control for participant age produced an inverse effect on the model statistics. Resultantly, participant age may have reduced the positive association between average BAC and the repeated measures differences. For subjective feelings of stimulation, the model statistics were reduced when subjective feelings of stimulation were controlled for (F(1,14) = 0.935, p = .350, $\eta^2_{Partial}$ = .063, 1 – β = .147). However, the linear influences on the Listening Recall repeated measures differences was not substantial based on the interaction in the model (F = 0.363, p = .555, $\eta^2_{Partial}$ = .025, 1 – β = .087) and linear correlation (r = .160, p = .555). Controlling for subjective feelings of stimulation slightly reduced the initial correlation between average BAC and the repeated measures differences (r = .113, p = .678) expressed by a partial correlation coefficient (r = .039, p = .890). Although both participant age and subjective feelings of stimulation played some role in the observed differences on the Listening Recall assessment, the role of "Stimulated" appeared to be minimal by comparison.

The Counting Recall subtest performance improved significantly during the experimental condition (F(1,15) = 5.403, p = .035, $\eta^2_{Partial}$ = .265, 1 – β = .585) but linear readings of average BAC were not particularly influential on the model statistics (F(1,14) = 4.998, p = .042, $\eta^2_{Partial}$ = .263, 1 – β = .548), as an interaction in the model (F = 0.846, p = .373, $\eta^2_{Partial}$ = .057, 1 – β = .138) or linear correlation (r = .239, p = .373). Therefore, although alcohol may have affected performance, no linear relationship to BAC readings was apparent. However, control for participant age resulted in a dramatic drop in the model statistics (F(1,14) = 0.024, P = .879, $\eta^2_{Partial}$ = .002, 1 – β = .052) although a weak interaction (F = 0.015, p = .905, $\eta^2_{Partial}$ = .001, 1 – β = .051) and correlation coefficient (r = -.032, p = .905) made interpreting this change challenging. However, when the partial correlation coefficient controlling for age in the relationship between average BAC and the repeated measures differences (r = .270, p = .330) is compared to the zero-order correlation (r = .239, p = .373), little change was observed. As a result, although age apparently affected the model statistics, the influence was not easily interpreted linearly. The same is true for the subjective stimulation scale, control for which also resulted in a drop in the model statistics (F(1,14) = 0.623, p = .443, $\eta^2_{Partial}$ = .043, 1 – β = .114) although the linear interaction effect of the model (F = 0.119, p = .735, $\eta^2_{Partial}$ = .008, 1 – β = .062) and correlation (r = .092, p = .735) were small. Additionally, change to the zero-order correlation between average BAC and the Counting Recall repeated measures differences (r = .239, p = .373) was not influential when "Stimulated" was controlled for in a partial coefficient (r = .223, p = .423). Therefore, although both participant age and subjective feelings of stimulation resulted in changes to the model statistics, these were not easily interpreted as a linear model and may have been due to another confounding influence. The same ambiguity is not true of the Backwards Digit subtest.

Performance on the Backwards Digit subtest improved during the experimental condition and the comparison model approached statistical significance (F(1,15) = 3.949, p = .065, $\eta^2_{Partial}$ = .208, 1 – β = .406), but control for average BAC resulted in only minimal change (F(1,14) = 3.256, p = .093, $\eta^2_{Partial}$ = .189, 1 – β = .039) and the linear interaction (F = 0.444, p = .516, $\eta^2_{Partial}$ = .031, 1 – β = .095) and correlation coefficient (r = .175, p = .516) suggested that linear measurements of average BAC were not influential in the model comparison. When participant age was controlled for, the model statistics increased slightly (F(1,14) = 5.403, p = .036, $\eta^2_{Partial}$ = .278, 1 – β = .581) and a strong linear relationship was present for age (F = 4.290, p = .057, $\eta^2_{Partial}$ = .235, 1 – β = .488). This was also demonstrated by the correlation coefficient between age and differences over the repeated measures (r = .484, p = .057). Furthermore, the relationship between average BAC and the repeated measures differences on the Backwards Digit subtest (r = .175, p = .516) increased substantially when age was controlled for using a partial correlation coefficient (r = .641, p = .010). As a result, participant age seemed to confound the true relationship between average BAC readings and changes in performance on the Backwards Digit subtest.

When the influence of participant age was removed, higher BAC readings were more strongly associated with deteriorations in performance. On the other hand, exclusion of the influence of subjective feelings of stimulation resulted in a reduced statistic in the comparisons model (F(1,14) = 0.012, p = .915, $\eta_{Partial}^2$ = .001, 1 – β = .051) and no clear linear relationship was present based on the model interaction (F = 0.258, p = .620, $\eta_{Partial}^2$ = .018, 1 – β = .076), nor was a strong correlation between "Stimulated" and the repeated measures differences (r = -.134, p = .620). Furthermore, subjective feelings of stimulation did not substantially alter the zero-order correlation coefficient between average BAC and the repeated measures differences on Backwards Digit (r = .175, p = .516) when a partial correlation coefficient was calculated (r = .281, p = .309). Consequentially, it appears that subjective feelings of stimulation had some effect on the model but this effect could not be clearly explained linearly.

Visuo-spatial Short-term Memory. The Dot Matrix subtest showed an improvement under the experimental condition but the change was not statistically significant (F(1,15) = 1.085, p = .314, $\eta_{Partial}^2$ = .067, 1 – β = .164). The F statistic was reduced when average BAC was controlled for (F(1,14) = 0.041, p = .843, $\eta_{Partial}^2$ = .003, 1 – β = .054) and the interaction (F = 0.430, p = .523, $\eta_{Partial}^2$ = .030, 1 – β = .094) and correlation coefficient (r = -.173, p = .523) illustrated that linear measurements of average BAC were not influential on the repeated measures differences. Unlike some of the verbal tests, control for participant age only slightly reduced the Dot Matrix model statistics (F(1,14) = 0.372, p = .552, $\eta_{Partial}^2$ = .026, 1 – β = .088) and weak linear relationships to the repeated measures differences and age were illustrated by the interaction effect (F = 0.239, p = .632, $\eta_{Partial}^2$ = .017, 1 – β = .074) and correlation coefficient (r = .130, p = .632). The relationship between average BAC and the repeated measures differences on the Dot Matrix (r = -.173, p = .523) was only fractionally altered by controlling for age (r = -.121, p = .669). Control for subjective feelings of stimulation did not have a large effect on the model statistics (F(1,14) = 0.894, p = .360, $\eta_{Partial}^2$ = .060, 1 – β = .143). The linear interaction in the model (F = 0.571, p = .463, $\eta_{Partial}^2$ = .039, 1 – β = .109) and correlation coefficient between subjective stimulation and the repeated measures differences (r = .198, p = .463) suggested little effect. However, the relationship between average BAC and the repeated measures differences (r = -.173, p = .523) became more negative when subjective feelings of stimulation were controlled for (r = -.318, p = .247). This represented some minor confounding influence of subjective stimulation on the association between average BAC and the repeated measures differences. In this case, it appeared that when subjective feelings of stimulation were excluded, higher average BAC readings were associated with improved, rather than deteriorated, performance. Unlike the Dot Matrix subtest, the Mazes Memory subtest performance deteriorated substantially under the experimental condition.

The deterioration in performance on the Mazes Memory subtest was not statistically significant but the effect size was medium in strength (F(1,15) = 2.517, p = .133, $\eta_{Partial}^2$ = .144, 1 – β = .318). Average BAC was influential based on changes in the model statistics (F(1,14) = 1.303, p = .273, $\eta_{Partial}^2$ = .085, 1 – β = .186) but the effect was not supported by a linear interaction in the model (F = 0.022, p = .884, $\eta_{Partial}^2$ = .002, 1 – β = .052) or correlation coefficients (r = -.040, p = .884). Controlling for participant age substantially altered the model statistics (F(1,14) = 0.034, p = .857, $\eta_{Partial}^2$ = .002, 1 – β = .053). Although this finding implied an influence of participant age, this was not supported in the model interaction (F = 0.000, p = .997, $\eta_{Partial}^2$ = .000, 1 – β = .050) or by the linear correlation coefficient (r = .001, p = .997). Furthermore, comparing the zero-order correlation between average BAC and differences on the Mazes Memory subtest (r = -.040, p = .884) and the partial correlation controlling for age (r = -.048, p = .865) illustrated the absence of a linear influence. Therefore, a more complex interrelationship was present. Control for the influence of subjective stimulation also reduced the model F statistic and effect size (F(1,14) = 0.025, p = .877, $\eta_{Partial}^2$ = .002, 1 – β = .053), but no simple linear interaction was present based on the interaction effect (F = 0.228, p = .640, $\eta_{Partial}^2$ = .016, 1 – β = .073) or correlation coefficient between "Stimulated" and the repeated measures differences on the Mazes Memory subtest (r = .127, p = .640). When the relationship between the Mazes Memory subtest difference and average BAC (r = -.040, p = .884) was adjusted using a partial correlation coefficient controlling for stimulated, an absolute magnitude increase in the negative direction was observed (r = -.119, p = .673). This finding was similar to that of the Dot Matrix visuo-spatial short-term memory subtest. The Block Recall subtest measuring visuo-spatial short-term memory responded similarly.

The fractional improvement in performance on the Block Recall subtest was not statistically significant (F(1,15) = 0.003, p = .957, $\eta_{Partial}^2$ = .000, 1 – β = .050). When average BAC readings were controlled for in a repeated measures analysis of covariance model, the statistic increased slightly (F(1,14) = 0.487, p = .497, $\eta_{Partial}^2$ = .034, 1 – β = .100) but no significant linear interaction was present (F = 0.798, p = .387, $\eta_{Partial}^2$ = .054, 1 – β = .133), and only a weak-moderate correlation coefficient was present (r = .232, p = .387). The model statistics did not change substantially when participant age was controlled for (F(1,14) = 0.650, p = .434, $\eta_{Partial}^2$ = .044, 1 – β = .117) and age did not have a strong linear interaction within the model (F = 0.649, p = .434, $\eta_{Partial}^2$ = .044, 1 – β = .117). The correlations demonstrated a weak to moderate, non-significant, tendency for older participants to show deteriorated performance during the experimental condition (r = .210, p = .434). The relationship between average BAC and the repeated measures differences (*r* = .232, *p* = .387) was altered by controlling for participant age in a partial correlation coefficient (*r* = .445, *p* = .096). The substantial alteration suggested interference of participant age in the relationship between alcohol consumption and the repeated measures differences on Block Recall where the association between higher BAC readings and deteriorations in performance became stronger. The same affect did not apply to subjective feelings of stimulation, control for which did not substantially alter the model statistics ($F(1,14) = 0.040$, $p = .844$, $\eta^2_{Partial} = .003$, $1 - \beta = .054$). No substantial linear interaction was present ($F = 0.046$, $p = .833$, $\eta^2_{Partial} = .003$, $1 - \beta = .055$) and there was a negligible correlation coefficient to the repeated measures differences on the Block Recall subtest (*r* = -.057, *p* = .833). Furthermore, the relationship between the Block Recall differences and average BAC (*r* = .232, *p* = .287) was not substantially altered when a partial correlation coefficient was calculated controlling for "Stimulated" (*r* = .301, *p* = .276). Therefore, it was apparent that only age played some role in the differences observed on the Block Recall subtest.

Visuo-spatial Working Memory. The Odd-one-out subtest scores improved under the experimental condition but the difference was not statistically significant ($F(1,15) = 0.143$, $p = .710$, $\eta^2_{Partial} = .009$, $1 - \beta = .065$). Average BAC seemed to have little effect on the model statistics ($F(1,14) = 0.645$, $p = .435$, $\eta^2_{Partial} = .044$, $1 - \beta = .116$) but the linear interaction was strong ($F = 2.077$, $p = .127$, $\eta^2_{Partial} = .129$, $1 - \beta = .269$). The correlation coefficient between the repeated measures differences on the Odd-one-out and average BAC showed a tendency for those with higher BACs to have improved performance under the experimental condition, although this was not statistically significant (*r* = -.359, *p* = .172). Participant age was clearly a contributor as control substantially altered the model statistics to achieve statistical significance ($F(1,14) = 6.601$, $p = .022$, $\eta^2_{Partial} = .320$, $1 - \beta = .667$) with a significant interaction ($F = 6.422$, $p = .024$, $\eta^2_{Partial} = .314$, $1 - \beta = .655$) and a strong correlation coefficient between age and the repeated measures differences (*r* = .561, *p* = .024). The zero-order correlation coefficient between average BAC and the repeated measures differences on the Odd-one-out subtest (*r* = -.359, *p* = .172) initially implied that higher BAC levels were associated with improved performance. However, control for participant age nullified this tendency when a partial correlation coefficient was calculated (*r* = -.050, *p* = .859). A similar, but weaker, effect was observed for subjective stimulation where the model statistics were altered ($F(1,14) = 2.155$, $p = .164$, $\eta^2_{Partial} = .133$, $1 - \beta = .277$) and the effect size of the interaction was medium-large ($F = 2.495$, $p = .137$, $\eta^2_{Partial} = .151$, $1 - \beta = .313$). A moderate linear correlation coefficient suggested that individuals feeling more "Stimulated" tended to show improved performance under the experimental condition (*r* = -.389, *p* = .137). This was opposite to the effect observed for age. However, control for "Stimulated" did not substantially alter the zero-order correlation coefficient when a partial correlation coefficient was calculated (*r* = -.208, *p* = .457). This implied that "Stimulated" was not as influential as participant age. However, the Odd-one-out subtest had only showed a small change in performance during the experimental condition. On the other hand, the Mister X subtest performance improved during the experimental condition.

Despite the difference being numerically larger, the improvement observed on the Mister X subtest was not statistically significant and the effect size was small ($F(1,15) = 1.418$, $p = .252$, $\eta^2_{Partial} = .086$, $1 - \beta = .200$). When average BAC was controlled for, the model statistics were reduced ($F(1,14) = 0.934$, $p = .350$, $\eta^2_{Partial} = .063$, $1 - \beta = .147$) but the interaction was not indicative of a linear effect ($F = 0.066$, $p = .800$, $\eta^2_{Partial} = .005$, $1 - \beta = .057$), nor was the correlation between average BAC and the differences (*r* = .069, *p* = .800). However, controlling for participant age had an effect on the model statistics ($F(1,14) = 4.222$, $p = .059$, $\eta^2_{Partial} = .232$, $1 - \beta = .481$) with a large effect size for the interaction ($F = 3.652$, $p = .077$, $\eta^2_{Partial} = .207$, $1 - \beta = .429$). Furthermore, the correlation between participant age and the repeated measures differences on the Mister X subtest was moderate and approaching statistical significance (*r* = .455, *p* = .077). The zero-order correlation between average BAC and differences on the Mister X subtest (*r* = .069, *p* = .800) was substantially increased when age was controlled for in a partial correlation coefficient (*r* = .459, *p* = .085), suggesting that higher average BAC scores were associated with deteriorations in performance if the influence of age is removed. The same was not true of the "Stimulated" scale, control for which did not substantially alter the model statistics ($F(1,14) = 0.426$, $p = .525$, $\eta^2_{Partial} = .030$, $1 - \beta = .093$). The linear interaction was minimal for "Stimulated" ($F = 0.825$, $p = .379$, $\eta^2_{Partial} = .056$, $1 - \beta = .135$). However, a slight tendency to improved performance under the experimental condition when levels of subjective stimulation were higher was indicated by the correlation coefficient (*r* = -.236, *p* = .379) although the magnitude was not sufficient to assume a clear relationship. Nonetheless, when subjective feelings of stimulation were controlled for, the weak relationship between average BAC and the repeated measures differences (*r* = .069, *p* = .800) increased substantially in a positive direction as a partial coefficient (*r* = .220, *p* = .430). However, unlike many of the subtests discussed thus far, the Spatial Recall subtest did not seem responsive to either age or "Stimulated".

The minimal deterioration in performance on the Spatial Recall subtest was not statistically significant and a small effect size was present ($F(1,15) = 0.258$, $p = .619$, $\eta^2_{Partial} = .017$, $1 - \beta = .258$). The model was not substantially influenced by controlling for average BAC ($F(1,14) = 0.084$, $p = .776$, $\eta^2_{Partial} = .006$, $1 - \beta = .058$) and no linear interaction was present ($F = 0.003$, $p = .958$, $\eta^2_{Partial} = .000$, $1 - \beta = .050$). Furthermore, the correlation between average BAC and the repeated measures differences was negligible (r = .014, p = .958). Control for participant age also did not alter the model statistics (F(1,14) = 0.021, p = .887, $\eta^2_{Partial}$ = .001, 1 – β = .052). Neither the model interaction (F = 0.007, p = .933, $\eta^2_{Partial}$ = .001, 1 – β = .051), nor the correlation between age and the repeated measures differences (r = -.023, p = .933), suggested that age had influenced changes in performance. Furthermore, removal of the influence of participant age from the average BAC to repeated measures difference correlation (r = .014, p = .958) resulted in a very similar magnitude of the partial correlation coefficient (r = .001, p = .996), confirming the lack of influence of participant age on changes in performance on the Spatial Recall subtest. The same findings were present for "Stimulated" for which control did not alter the model statistics (F(1,14) = 0.080, p = .782, $\eta^2_{Partial}$ = .006, 1 – β = .058) or result in a large model interaction (F = 0.035, p = .854, $\eta^2_{Partial}$ = .003, 1 – β = .054) or linear correlation between subjective feelings of stimulation and the repeated measures differences (r = -.050, p = .854). The absence of influence was confirmed when the partial correlation coefficient controlling for "Stimulated" in the relationship between average BAC and the repeated measures (r = .045, p = .873) was shown to be highly similar to the zero-order correlation (r = .014, p = .958). Although a number of the AWMA subtests were shown to be influenced by breath alcohol levels, age and subjective feelings of stimulation, the effects were inconsistent. In general, control for age created a more positive relationship between average BAC and the repeated measures differences, suggesting a natural tendency towards deteriorations in performance at higher BAC levels.

Discussion and Findings

Although the findings of the present research were both congruent and incongruent with the literature, some important outcomes emerged. Acute alcohol consumption affected the short-term memory and working memory subtests differently. Furthermore, the individual subtests were affected differently. This finding highlighted the importance of task type. Although the short-term memory subtests showed variable directions of change over the two conditions, both the verbal and visuo-spatial working memory subtest sets improved during the experimental condition. The only short-term memory subtest showing a substantial effect size for the comparisons was the deteriorated performance on the visuo-spatial Mazes Memory task. Improvements on the visuo-spatial Dot Matrix subtest were also worth acknowledgement based on the effect size. All of the verbal working memory subtests improved markedly during the experimental condition and many exhibited large effect sizes in the models. The visuo-spatial working memory subtests also improved, but to a lesser extent. These findings excluded the visuo-spatial Spatial Recall subtest. However, the analyses revealed that the influence of alcohol on this improvement was complex and subject to interrelationships, particularly with participant age which tended to magnify the model statistics and, in some cases, altered the relationship between average BAC and the repeated measures differences. The findings suggested that although average BAC levels may be associated with deteriorating performance, the fact that younger participants had higher BAC readings while older participants tended to show deteriorated performance may have produced a confounding influence. On the other hand, subjective feelings of stimulation were related to both average BAC and age but were not as influential over the repeated measures differences. The findings implied that alcohol may have had a general influence on performance, subject to the influence of age and subjective feelings of stimulation, which could not necessarily be linearly accounted for by average BAC readings, particularly given the low dosage. As a result, the themes emerging from the present research deal with these potential influences and, in particular, focus on known changes following alcohol consumption such as stimulus discrimination and evaluation, attentional states and the importance of task type.

The Influences of Alcohol on the Components of Working Memory

The majority of the reviewed literature reported alcohol-related deficits on short-term and working memory tasks (e.g. Lechner et al., 2016; Saults et al., 2007). In the present research, performance on short-term tasks generally declined and, although this was inconsistent, the finding was congruent with similar research studies using similar tasks (e.g. Cromer et al., 2010; Dougherty et al., 2000; Lechner et al., 2016; Saults et al., 2007; Weissenborn & Duka, 2003). However, the working memory task performance improved consistently, particularly in the verbal domain. In this regard, some research has suggested that certain types of working memory task could improve following alcohol consumption, particularly learning-oriented and evaluative tasks (Carlyle et al., 2017; Klingberg, 2010; Steele & Josephs, 1988). The inconsistent effect on the different tasks used in the present study suggested that factors other than basic storage capacity may have been influenced differently by the low dose of alcohol consumed. Sklar and Nixon (2014) suggested that some of these differences could be accounted for by the impact of alcohol on the formation of specific stimulus representations for short-term memory storage.

Alcohol-related changes in short-term memory task performance could be due to deficits in the sensory ability to form representations of stimuli and discriminate between highly similar stimuli (Dougherty et al., 2000;

Sklar & Nixon, 2014). The Nonword Recall subtest of the AWMA, for example, would require the formation of auditory stimulus representations which could not be linked to contextually-relevant information thereby resulting in a deficit in performance. In other cases, the disruption to stimulus discrimination and representation could be compensated for if contextual representations can be used as a compensatory mechanism for rehearsal and recall (Curhan et al., 2014; Pitel et al., 2007; Sklar & Nixon, 2014). Therefore, different task types measuring short-term memory could be differently affected by alcohol consumption. In the present research, the context-free Nonword Recall subtest was more negatively affected by the contextually-relevant Word Recall subtest. Additionally, abstract representation tasks, such as the Mazes Memory subtest, were more affected than serial positioning tasks (cf. Weissenborn & Duka, 2003 regarding abstract representations). In such cases, disruptions in immediate stimulus representation could explain the disproportionate effects of alcohol on the short-term memory task performances. Although disruptions to sensory stimulus evaluation and discrimination may influence short-term memory task performance, the majority of comparable literature has focused on the impact of alcohol complex executive function processes. On the other hand, the present research utilised working memory processing tasks which required stimulus evaluation coupled with, potentially, tacit recall.

Studies on the impact of alcohol on working memory and executive function have generally not directly investigated processing components, rather focusing on global tasks such as information monitoring (e.g. Trail Making Test in Lechner et al., 2016), planning (e.g. Tower of London Test in Saults et al., 2007) and contingency monitoring (e.g. Wisconsin Card Sorting Test in Lyvers & Tobias-Webb, 2010). In the present research, the working memory tasks focused primarily on stimulus evaluation coupled with recall, which may have been tacit. For example, Alloway (2007) described the Listening Recall subtest as requiring participants to evaluate a sentence as true or false, and then recall the final word of each sentence in order of presentation. In the Visuo-spatial Working Memory composite, the Mister X subtest required the participants to identify whether the ball was being held in the same versus opposite hand, followed by the recollection of the position of the ball in the correct order. Resultantly, the working memory processing tasks required both an evaluation and recall component. These components may have been differently affected by alcohol in comparison to executive function tasks. Resultantly, if stimulus evaluation remained intact while regulative recall was negatively affected (e.g. Curtin & Fairchild, 2003), the AWMA working memory processing tasks may have permitted tacit recall. However, performance on these tasks may also be related to attention allocation functions, known to be influenced by alcohol consumption, affecting the separate task types differently. This is particularly true in light of the additional time utilised by the participant to evaluate the stimulus prior to recall.

Alcohol consumption influences attentional functions, allocations and deliberate response selections (Curtin & Fairchild, 2003; Klingberg, 2010) Therefore, changes in performance could be related to the effect of alcohol on focusing attention and deliberately attending to information (Bartholow et al., 2003; Fleming et al., 2013; Schweizer & Vogel-Sprott, 2008; Steele & Josephs, 1988). As a result, short-term memory tasks requiring deliberate, focused attention may be more prone to deficits (e.g. Curtin & Fairchild, 2003; Finn et al., 1999; Lechner et al., 2016). In context of the present findings, deficits in both focused attention and response selection could have resulted in the short-term memory task changes observed without influencing the working memory processing tasks as these may have been subject to a diffuse attentional state. Broad stimulus evaluation, subliminal rehearsal, reduced susceptibility to distraction and automatic responding have been associated with diffuse attentional states as well as facilitated performance on certain working memory type tasks (Abroms, Gottlob, & Fillmore, 2006; Carlyle et al., 2017; Curtin & Fairchild, 2003; Erblich & Earleywine, 1995; Maylor, Rabbitt, James, & Kerr, 1990; Schulte, Muller-Oehring, Strasburger, Warzel, & Sabel, 2001; Tracy & Bates, 1999). Using a test similar to the AWMA Listening Recall subtest, Jarosz, Colflesh and Wiley (2012) attributed improvements in performance following alcohol consumption to diffuse, rather than focused, attention permitting tacit recall. In the present research, a diffuse attentional state may have enhanced broad stimulus evaluation, automatic responding, tacit recall or tacit storage. This would result in an absence of clear deficits on the working memory tasks, particularly if effortful attention was not required for rehearsal strategies or deliberate response selection from short-term memory (Ratti et al., 2002). Furthermore, as Autin and Croizet (2012) contend, directed attention may be associated with increased self-evaluation which could hinder performance on certain task types.

Alcohol consumption has been shown to reduce self-awareness of performance, task-demand perceptions, general metacognitive monitoring, self-evaluative behaviours and meta-awareness of responses (Baumeister & Alghamdi, 2015; Cabeza & Nyberg, 2000; Eysenck & Calvo, 1992; Hull, 1981; Hull, Levenson, Young, & Sher, 1983; Mason et al., 2007; Oscar-Berman & Marinković, 2007; Ridderinkhof et al., 2002) while facilitating inadvertent learning and memorisation (Carlyle et al., 2017). Furthermore, response inhibitions and overall cognitive monitoring may be reduced (Cohen-Gilbert et al., 2017; Müller & Knight, 2006; Park et al., 2011), causing deficits on short-term memory tasks but not necessarily stimulus evaluations or tacit recall as demanded by the AWMA working memory processing tasks. As a result, activities such as self-checking and order monitoring may have been affected by alcohol differently to activities such as stimulus evaluation or inadvertent remembering. Although alcohol may have had an impact on a variety of factors, the responses observed in the present research were not always consistent with the literature, particularly for the working memory processing tasks. However, the results demonstrated that participant age was influential in a number of cases and may have attenuated the purportedly positive relationship between alcohol consumption and deficits in performance.

Participant Age

Control for participant age exaggerated, or reduced, the statistical differences over the repeated measures in many cases. However, the affect was inconsistent but did not seem to depend on task type or whether the task was based in the verbal or visuo-spatial domain. In general, controlling for participant age strengthened the relationship between average BAC readings and differences over the repeated measures in a direction indicating an association with deficits in performance. Therefore, when age was controlled for higher average BAC readings were more strongly associated with tendencies toward deteriorations in performance in the alcohol consumption condition. The confounding influence might have been a result of the significant negative relationship between participant age and average BAC readings which indicated that younger participants tended to record higher average BAC levels. This finding was contrary to the majority of research which indicated that older individuals record higher BAC levels following alcohol consumption (e.g. Acheson, Stein, & Swartzwelder, 1998; Jones & Jones, 1980; Tynjälä, Kangastupa, Laatikainen, Aalto, & Niemelä, 2012; Vogel-Sprott & Barrett, 1984). In the present research, this difference could not be accounted for by general consumption levels, binge drinking habits, body mass index or general lifestyle habits.

Research has demonstrated declined short-term and working memory functions with advancing age, including complex information processing and reduced cognitive load capacity (Cappell, Gmeindl, & Reuter-Lorenz, 2010; Nittrouer et al., 2016; Reuter-Lorenz et al., 2000; Salthouse, 1994; Salthouse, Mitchell, Skovronek, & Babcock, 1989; Schroeder, 2014; Shaw et al., 2006), but the participant age range in the present research was unlikely to have been influenced by these natural processes. Additionally, baseline performance was controlled for via the repeated measures method. As a result, although factors such as response accuracy, speed of response and sensory processing are influenced by both alcohol and normal aging (Gilbertson, Ceballos, Prather, & Nixon, 2009; Sklar, Gilbertson, Boissoneault, Prather, & Nixon, 2012), in the present study it is unlikely that the changes observed were due to normal aging processes alone. However, only limited research has explored the combined effects of alcohol and aging on working memory performance (e.g. Acheson et al., 1998; Gilbertson et al., 2009; Vogel-Sprott & Barrett, 1984).

Limited studies have suggested that complex simulation tasks and working memory tasks are affected by alcohol consumption without an age-dependent component (Vogel-Sprott & Barrett, 1984; Yesavage, Dolhert, & Taylor, 1994). However, Acheson et al. (1998) reported greater alcohol-related impairments in semantic and figural memory in participants between 21 and 24 years of age compared to those between 25 and 29 years of age. Acheson et al. (1998) also used a repeated measures design to control for baseline ability, although BAC levels were not reported, and suggested that age does influence the impact of alcohol on short-term and working memory. These findings, despite being contrary to those of the present research, suggest that an age-dependent effect of alcohol on working memory is possible even in a younger cohort without the influence of normal aging. Although participant age appeared to be influential and was related to average BAC levels, subjective feelings of stimulation were also associated with both variables.

Subjective Stimulation

Subjective feelings of stimulation were measured using the Brief Biphasic Alcohol Effects Scale (B-BAES), a shorter version the Biphasic Alcohol Effects Scale (Earleywine & Erblich, 1996; Martin et al., 1993; Rueger & King, 2013). Feelings of beings stimulated during the ascending limb of the BAC curve are common as part of a biphasic effects profile, as are feelings of sedation during the descending limb (Earleywine & Erblich, 1996; Martin et al., 1993; Morean & Corbin, 2010; Quinn & Fromme, 2011). Based on tentative correlational findings, the present study's findings concurred with the proposed structure of the B-BAES (Earleywine & Erblich, 1996; Martin et al., 1993; Rueger & King, 2013). The derived average level of "Stimulated" scale was for further analyses. Despite being correlated with average BAC readings, subjective stimulation did not have as strong an impact as participant age. In most cases, the effect of subjective feelings of stimulation was negligible and did not influence the relationship between average BAC and the repeated measures differences. Nonetheless, other research has suggested that such an effect is possible, although difficult to measure and study.

Research has shown an absence of effect of subjective feelings of stimulation on working memory task performance following alcohol consumption (Cromer et al., 2010) but suggested that subjective sedation may be associated with more impulsive responding (Shannon, Staniforth, McNamara, Bernosky-Smith, & Liguori, 2011). Therefore, the subjective sedative effects of alcohol may be more important than the stimulating effects focused on in the present research. However, other researchers have hypothesised that reported feelings of stimulation are the result of an expectancy following alcohol consumption, rather than actual stimulation (Earleywine, 1994; Leonard & Blane, 1988), and that subjective stimulation does cause deficits in performance provided it is anticipated (Marczinski, Fillmore, Henges, Ramsey, & Young, 2012). Although expectations of feeling stimulated may change performance on working memory tasks, the effect might only be relevant for high risk groups such as heavy drinkers (Earleywine, 1994). However, the present sample did not demonstrate a relationship between alcohol-related lifestyle characteristics and reported feelings of subjective stimulation. Much of the research on the influence of subjective stimulation on performance may not be generalisable to the present findings as known stimulants, such as energy drinks, were utilised rather than alcoholic beverages. Therefore, the absence of expectancy may have altered the influence of subjective stimulation in the present research. Although a number of the alcohol-related changes discussed could have influenced the outcomes of the present research, several limitations were present which should be considered during interpretation of the findings.

Limitations

Research methodology. The rigorous sampling implemented in the present research reduced extraneous variance due to intrapersonal and physiological characteristics, resulting in the preferable homogenous sample (Hair et al., 1987; Rosenthal & Rosnow, 2008). Although homogenous samples lack generalisability, for experimental research they can provide a better test of theory under controlled conditions, especially if random, representative samples are not obtainable or practicable (Howitt & Cramer, 2011; Rosenthal & Rosnow, 2008). However, the sampling protocol also resulted in a smaller sample size which created challenges in data analysis despite the sufficient dispersion observed and confirmatory bootstrapping analyses (Hoyle, 1999). Nonetheless, other research in the field has made use of similar sample sizes for group comparison analyses and research studies with smaller sample sizes of between 10 and 20 have reported similar findings to those with larger sample sizes, even when using group comparisons methods (e.g. Cromer et al., 2010; Montgomery et al., 2011; Pualus et al., 2006).

As opposed to these group comparisons, the use of repeated measures in the present research mitigated the smaller sample size to some extent by reducing the risk of between-persons variance inherent in group comparison studies (Howitt & Cramer, 2011). Furthermore, error variance is explicable in terms of individual difference which is automatically controlled for along with extraneous error (Blackwell, de Leon, & Miller, 2006; Howitt & Cramer, 2011). However, control for covariates, such as participant age in the present research, remains essential (Bartko, 1966; Blackwell et al., 2006; Schwartz & Stone, 1998). Although Schweizer et al. (2006) and Claus and Hendershot (2015) attempted similar methods, both studies suffered from short delay periods and likely practice effects acting as a covariate in the repeated measures comparisons.

Test-retest delay. Performance on cognitive tasks can improve during second administrations even using lengthy delay periods (Bird, Papadopoulou, Ricciardelli, Rossor, & Cipolotti, 2004; Maylor et al., 1990). However, some have contended that improvements are only applicable to complex tasks and not recall-based tasks (Jonides et al., 2008; Klapp, Marshburn, & Lester, 1983) in which short-term recall acts as a limiter for working memory performance without being directly influenced by practice effects (McEvoy, Smith, & Gevins, 1998). The present research did not use a set delay period due to sampling and practical constraints although the recommended four-week minimum period exceeded that cited in the literature (e.g. Anastasi & Urbina, 1997). Some research has considered delay periods between administrations in conjunction with alcohol consumption, finding that both influence relaxation, anxiety levels, attentional focus and other common factors (Bird et al., 2004; Hausknecht, Halpert, Di Paolo & Moriarty-Gerrard, 2007; Lo et al., 2012; Maylor et al., 1990; Cromer et al., 2010; Schweizer et al., 2006). However, research studies including both alcohol consumption and repeated measurements did not report an effect of short test-retest delay periods and have suggested that alcohol should negate practice effects (Bartels, Wegrzyn, Wiedl, Ackermann, & Ehrenreich, 2010; Cromer et al., 2010; Jarosz et al., 2012). The inconsistent delay periods implemented in the present research, along with the lower dosage of alcohol, may have caused challenges in interpreting the data. Research studies have supported the presence of practice effects even after lengthy delays (e.g. Bird et al., 2004; Hausknecht et al., 2007) as well as a mitigating effect of alcohol (e.g. Bartels et al., 2010; Cromer et al., 2010; Schweizer et al., 2006). Although test-retest delay may have been influential in the present within-person comparisons, the design did permit the use of the smaller sample without unduly sacrificing statistical quality. However, the present delay periods were not standardised, introducing extraneous variance although additional models accounting for this covariate did not suggest a conclusive effect. Another important difference in the present research was the dosage of alcohol utilised.

Alcohol administration, absorption and the measurement of intoxication. A prominent limitation of the present research was the use of a small dose of alcohol (13.6 grams by volume) rather than the more substantial, calculated doses used in other studies. Comparable research has made use of higher alcohol dosages usually relevant to body weight and drinking habits of the participants (e.g. Claus & Hendershot, 2015; Saults et al., 2007; Weissenborn & Duka, 2003). Other studies have focused on achieving specific peak breath alcohol concentrations of a specific value (e.g. Lyvers & Maltzman, 1991). Lechner et al. (2015) made use of a dosage of 0.4g/kg body mass as a low dosage condition which produced different findings, notably an absence of impairment, to that of a moderate dose condition comparable to Weissenborn and Duka’s (2003) 0.8g/kg administration. In both cases, the calculated dosages were considerably higher than that administered in the present research, perhaps contributing to the differences in the research findings.

Hoffman et al. (2015) and Lechner et al. (2005) both suggested that subclinical doses may not produce significant impairments in comparison to higher doses, particularly since BAC readings return to 0.00 within a considerably shorter timeframe. Furthermore, the measurement of breath alcohol concentrations is not necessarily indicative of an influence on performance (Cromer et al., 2010) which can remain impaired for some time after participants no longer report inebriation and BAC levels have returned to zero. Some research suggests that a 30-90 minute time frame is required for full absorption, despite being incongruent with BAC readings (Dubowski, 1985; Zakhari, 2006). The present research made use of progressive measurements of BAC levels to accurately account for changes in the BAC curve over time. Therefore, rather than achieving a peak dosage for comparison to a control group, or other dosage groups (e.g. Grattan-Miscio & Vogel-Sprott, 2005), an average reading was recorded. Coupled with the randomisation of the experimental condition subtest order, the use of progressive readings with an average calculation mitigated challenges in controlling for changes over the BAC curve where different peaks have been linked to differential effects of alcohol consumption (e.g. Saults et al., 2007; Schweizer et al., 2006). However, due to the combination of the low dosage of alcohol, averaging of readings and sensitivity of the equipment to two decimal places, tied ranks were present. Additionally, the lengthy assessment time frame may have impacted the findings. Resultantly, although a consistent curve of BAC readings was present, the average readings lacked the ideal range and dispersion of scores. Although research such as that of Schweizer et al. (2006) has considered positioning on the BAC curve, no published research located appears to have incorporated the use of specific BAC reading values as a covariate for comparative purposes in modelling over repeated measures.

Conclusion and Recommendations

The twelve AWMA measures of verbal and visuo-spatial short-term and working memory were differently affected by a low dose of alcohol. The repeated measures (test-retest) design used in the present study allowed for control of baseline ability. While the repeated measures design presented a unique opportunity to understand the influence of alcohol free of individual variations in participants in the different groups, other factors such as participant characteristics, subjective stimulation and practice effects due to inconsistent delay periods may have been influential. Nonetheless, performance on the working memory subtests, particularly the verbal subtests, improved. On the other hand, performance on some of the short-term memory subtests deteriorated. Linearly, the low dose of alcohol was sometimes associated with changes in performance. The negative influence of alcohol on performance was often attenuated by participant age, despite the 21 years to 35 years truncation. Although subjective feelings of stimulation were associated with alcohol consumption, perceptions of being stimulated were not associated with changes in performance. The present findings that covariates, particularly participant age, influence the impact of alcohol on changes in working memory are of particular importance as the majority of research has not considered the role of covariation in a within-persons design. However, these influences, as well as the role of alcohol consumption, may be different to that found in the present research if higher dosages are considered, or larger samples are obtained. Factors such as peak absorption time, which is subject to individual variations, also require consideration and may have been influential in the results seen for the present research. These issues require further investigation utilising carefully designed studies with similar, stringent, sampling requirements to those used in the present research. The present research study found that certain aspects of short-term and working memory may improve following alcohol consumption but the precise effect of alcohol is challenging to understand, particularly if covariates such as age are considered. Younger participants recorded higher BAC levels and even low BAC levels may be associated with changes in executive-function based activities, particularly those requiring focused attention and deliberate action. Furthermore, changes following alcohol consumption may cause impairment in deliberate focus, recall of information relating to the practical implications of alcohol or disregard for immediately presented health and safety information. These changes may have practical consequences following even low doses of alcohol consumption.

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