Alcohol & Alcoholism Vol. 35, No. 2, pp. 197–201, 2000

ALCOHOL IMPAIRS SPEED OF INFORMATION PROCESSING AND SIMPLE AND CHOICE REACTION TIME AND DIFFERENTIALLY IMPAIRS HIGHER-ORDER COGNITIVE ABILITIES

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(*Received* 7 *July* 1998; *in revised form* 14 *August* 1999; *accepted* 20 *September* 1999)

Abstract — Previous research has demonstrated that alcohol impairs information processing. However, it is unknown whether this impairment is on all stages of information processing, or on the early, rather than on the later, stages of information processing. Thus, the aim of the present study was to examine the effects of orally administered alcohol on both the early and the later stages of information processing. The present study assessed inspection time (IT), simple reaction time, choice reaction time and cognitive ability (Wechsler Adult Intelligence Scale — Revised) in 16 adult participants in both alcohol and placebo conditions. IT (a measure of the early stages of information processing) was used as a predictor variable in a linear regression to examine whether a disruption of the early stages of information processing accounted for changes in total information processing after alcohol administration. Results indicated that alcohol significantly slowed total information processing, independently of the early stages of information processing.

INTRODUCTION

Previous research has demonstrated an impairment of information processing following alcohol administration (Koelega, 1995). Studies examining different stages of information processing, such as reaction time (RT), vigilance and cognition indicate that increased blood alcohol concentration impairs performance on such tasks. The purpose of the present paper is to further examine this effect by evaluating the influence of alcohol on the early stages of information processing. The introduction reviews previous research examining the relationship between alcohol and information processing.

EARLY STAGES OF INFORMATION PROCESSING

The early stages of information processing have been described as those which involve the detection of and response to simple stimuli (Koelega, 1995). A task that assesses this function is the inspection time (IT) task, which has recently been demonstrated to be sensitive to pharmacological agents (Stough *et al*., 1995) and is the most reliable and valid culture-fair information processing measure of cognitive ability (Deary and Stough, 1996). IT has previously been used to assess the effects of nicotine on speed of information processing and is generally regarded as a measure of the speed of the early stages of information processing, such as the speed of visual encoding. As IT involves the ability to make an observation/inspection of sensory input on which a discrimination of relative magnitude is based, it is contrasted to tasks such as reaction time (RT), which generally involve more response-oriented measures of total decision-making time, that constitute total information processing.

Although no research has examined the effects of alcohol administration on IT, there are a few studies that have examined the effects of alcohol on the early stages of information processing utilizing other tasks. Maylor *et al*. (1990), using a visual-tracking task, found that speed of detection was impaired by alcohol and that these effects were greater under dual-task conditions compared to single-task conditions. Such results have been described as the deleterious effects of alcohol on central processing capacity and on the availability of information processing capacity over time (Rohrbaugh *et al*., 1988).

Jaaskelainen *et al*. (1995) investigated early information processing by examining the mismatch negativity (MMN) component of the auditory event-related potential (ERP), and reported that low doses of alcohol attenuated the ERP signal. MMN suppression was stronger when stimulus deviation was smaller, indicating that, at a relatively low blood-alcohol concentration (BAC), the detection of small deviations, such as that required in the IT task, is especially hampered. Similar results have been found in simple RT tasks with two levels of stimulus intensity. In these studies alcohol resulted in increased RT and impaired stimulus detection, suggesting an influence on sensory–perceptual processes and degree of attentiveness (Krull *et al*., 1994).

TOTAL INFORMATION PROCESSING

Unlike the early stages of information processing, there has been considerable research into the effects of alcohol on total information processing, measured by RT, vigilance and attention tasks and tasks assessing cognitive ability. Generally, results suggest that, when demands are higher, such as under dual-task conditions, the impairment in performance due to alcohol becomes more significant (Maylor *et al*., 1990). For example, Bartl *et al*. (1996) found alcohol to produce three times more errors on a concentration task, two times more errors on an RT task and two times more errors in a visual structuring task, when compared to performance in a placebo (no alcohol) condition. Similarly, Mayor *et al*. (1992) found that errors increased with task complexity measured by 2-, 4- and 8-choice RT tasks.

Research into the effects of alcohol on simple visual and auditory RT has concluded that even a low dose of alcohol can

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impair performance, generally demonstrated by an increase in RT (Gustafson, 1986*a*,*b*,*c*; Lemon *et al*., 1993). This type of impairment has been linked to the existence of a facilitation of performance that precedes impairment. It is suggested that information processing could be impaired at the same time that motor functions are facilitated, hence, false alarms and errors occur (premature reactions) (Kraepelin, 1892). This view has been supported by Levine *et al*. (1975), who found that low levels of alcohol deleteriously affect attention and information processing, rather than motor coordination.

Total information processing also involves higher-order cognitive functions, such as learning and memory. The Wechsler Adult Intelligence Scale — Revised (WAIS-R) is a good tool for examining such higher-order cognitive processes (Wechsler, 1981). Although no research has examined the effects of alcohol on the WAIS-R, there has been research into the effects of alcohol on complex information processing using tasks that involve word recall and recognition, memory, creativity and cognitive–motor performance.

The effects of alcohol on memory have been previously examined using tests of free recall. Lister *et al*. (1991) compared the effects of alcohol on implicit and explicit memory and found that alcohol impaired ability to explicitly remember words, but did not impair memory for the same material when assessed implicitly. Hence, it was concluded that the effects of alcohol on memory are selective.

Jubis (1986) reported that performance on a free recall of relevant cues was enhanced with a moderate dose of alcohol. It was explained that, as alcohol induced arousal, attention to high-priority task components was enhanced. In such cases, speed and accuracy were unaffected (Fleming *et al*., 1983; Williams and Rundell, 1984).

Word categorization and recognition tasks also assess complex cognitive processes. Alcohol decreases performance in word categorization tasks by inducing slower and less accurate responses, whereas in word recognition tasks, alcohol can result in more accurate semantic processing (Maylor *et al*., 1987) or impaired performance (Williams and Rundell, 1984).

Creativity is another aspect of cognitive ability that is modified by alcohol. Interestingly, alcohol has been shown to impair creativity in individuals whose performance is high in a placebo condition. For individuals whose performance is low in a placebo condition, alcohol enhances creativity (Lowe, 1994). In addition, it has been reported that creative thought is impaired even in placebo conditions, which has been explained as the influence of the expected effects of alcohol on the production of creative solutions (Gustafson, 1991).

THEORIES ON IMPAIRMENT OF INFORMATION PROCESSING

There are several interpretations of how alcohol impairs total information processing. Rohrbaugh *et al*. (1988) suggested that impairment of the early stages of information processing by alcohol may be the cause of decreased performance in tasks that require continuous performance, suggesting a chain reaction of impaired early stages to later stages that make up total information processing.

Research into visual spatial attention, on the other hand, suggested that all stages of information processing are impaired independently. It is suggested that alcohol impairs performance only in tasks that place greater demands on visual spatial attention. This impairment is said to occur via a disruption of the ability to shift attention from one spatial locus to another, generally not required in tasks assessing the early stages of information processing (Post *et al*., 1996). This theory is supported by Koelega (1995), who stated that most tasks assessing early information processing are less sensitive to the effects of alcohol (Linnoila, 1974; Miles *et al*., 1986; Fagan *et al*., 1987). This suggests that alcohol only impairs later stages of information processing that involve higher demands, and hence impairment in total RT is likely to occur independently of the early stages (Miles *et al*., 1986).

It is not yet clear whether impairment of the early stages of information processing is the cause of observed impairment in total information processing, as there is no previous study that has systematically addressed this question. What is required is the examination of the effects of alcohol on the early stages of information processing (measured by IT) together with the total stages of information processing (measured by RT: simple and complex and the WAIS-R). If alcohol impairs total information processing independent of the early stages, then it may be concluded that alcohol impairs more than just the early stages of the information processing chain.

Thus, the present study examined the relationship between alcohol and a range of psychological measures ranging from the early stages of information processing (IT) to more complex total information processing (simple RT, complex RT, and WAIS-R). In order to differentiate between the effects of alcohol on the 'early' and 'total' information processing, IT was used as an independent variable in linear regression equations.

MATERIALS AND METHODS

Participants

Sixteen right-handed volunteers were recruited from the general community (eight males and eight females). Ages ranged from 18 to 29 years (mean 15.06, SD 2.08). All had at one time previously consumed alcohol and all participants stated that they were aware of the general effects of alcohol. The research was approved by the Swinburne University Human Research Ethics Committee and all participants provided written informed consent.

Apparatus

The placebo condition involved a beverage that was made up of 240 ml of orange juice (60% orange juice, 40% water and sugar). The alcohol condition involved a beverage that was made up of 40 ml of vodka (40% alcohol) and 200 ml of orange juice (60% orange juice, 40% water and sugar). A Lion Alcolmeter S-D2 was used to measure participants' BAC. A Snellen visual acuity chart was used to ascertain visual acuity. Computerized neuropsychological tasks were installed on a 486 notebook computer where responses involved pressing particular buttons on the keyboard.

Inspection time (IT)

Instructions for the IT task emphasized that the procedure involved accurate, not rapid responding. Participants were told that the task involved simple visual discriminations in which they were required to judge which one of two lines was the shortest. A cue was presented for 500 ms prior to the stimulus onset, which consisted of two parallel vertical lines 24 mm and 34 mm long separated by 10 mm. Participants were required to respond by pressing a left key if the shortest of the two lines appeared on the left side and a right key if the shortest line appeared on the right side. The shortest line had equal probability of occurrence on the left or right side of the long line. The two lines were joined by a horizontal bar across the top of each line. Following the presentation of the cue, the stimulus was presented for a variable duration, ranging from 16 to 240 ms and then followed by the mask that was presented for 360 ms. The inter-stimulus interval was varied by each subject as the next trial would only proceed after the subject pressed a button. However, the time between the preceding response and the onset of the cue for the next trial was 2000 ms. Participants were instructed to respond as accurately as possible. Participants were given 10 practice trials at both 200 and 100 ms stimulus duration and were also tested for visual acuity with the Snellen eye chart and those with poor visual acuity omitted from further participation. A PEST procedure (Taylor and Creelman, 1967) was used to vary stimulus duration across trials and subsequently to determine each subject's IT score (i.e. stimulus duration required for 80% responding accuracy). The initial stimulus duration was 144 ms for all participants and eight reversals were required before an IT estimate could be made.

RT

Simple and complex RT were measured using a computerized neuropsychological programme. The objective of the task was to respond to a stimulus as it appeared on the screen, as quickly as possible. The complex RT task was a complex multiple-choice one in which each subject was requested to choose between eight possible responses.

Cognitive ability

Cognitive ability was measured using several subtests of the WAIS-R. The following performance scale subtests were administered: picture completion (PC), picture arrangement (PA), block design (BD), object assembly (OA) and digit symbol (DS). In addition, the digit span [digit forward (DF) and digit backwards (DB)] subtests from the verbal scale were administered. These tests were used to measure cognitive processes involving perceptual organization, short-term memory, visual memory, freedom from distractibility and anxiety, visuo-motor coordination, synthesis of thought, abstract thought, common sense, decision making, and attention to detail (Sprandel, 1995).

Procedure

The experiment comprised a placebo and alcohol (experimental) condition. Each session was conducted 2 weeks apart, at the same time of the day for each participant. The order of administration of the placebo and experimental conditions was balanced for all participants. Informed consent and demographics were completed in the first session. Participants were asked not to consume alcohol at least 3 days before testing, and asked not to eat at least 2 h before testing. The battery of tests was administered, immediately after subjects reached the required BAC, in the following order: WAIS-R subtests, simple RT, complex RT and IT. The completion of all tests took ~30 min.

In the placebo condition, participants' BAC was measured; if the BAC was zero, participants were administered three glasses of a non-alcoholic beverage followed by the battery of tests. In the alcohol condition, three glasses of the alcoholic beverage were administered until BAC reached 0.05% (50 mg/dl). If BAC was <0.05%, a further alcoholic beverage was administered. If BAC was >0.05%, subjects were asked to wait until BAC dropped to 0.05% before proceeding. The battery of tests was administered as soon as BAC was 0.05%.

RESULTS

A series of paired sample *t*-tests was conducted to examine whether there were any significant relationships between the placebo and alcohol conditions for IT, simple RT, complex RT and the WAIS-R subtests, and the results are shown in Table 1.

IT

IT was significantly longer (i.e. slower information processing increased) [$t(15) = –3.25$, $P < 0.005$] in the alcohol (0.05% BAC) condition, compared to placebo conditions, suggesting that alcohol impairs the speed of the early stages of information processing.

Simple RT and complex RT

Both simple and complex RT was longer when BAC was 0.05% than when BAC was zero, indicating that alcohol slows both simple and complex information processing [simple RT: $t(15) = –2.35$, $P < 0.05$; complex RT: $t(15) = –3.02$, $P < 0.005$].

Cognitive ability

Only some of the subtests from the WAIS-R were significantly different across the two alcohol conditions. Performance was better in the placebo condition than in the alcohol condition for: PC [$t(15) = 4.07$, $P < 0.005$], PA [$t(15) = 4.37$, $P < 0.005$], and OA [$t(15) = 4.32$, $P < 0.05$] but not for BD, DS, DF and DB. Alcohol administration resulted in impaired performance on perceptual organization, synthesis of thought, abstract thought, decision making and attention to detail, but not on short-term memory, visual memory, freedom from distractibility and anxiety and visuo-motor coordination.

Table 1. Parameters of information processing at blood-alcohol concentrations (BAC) of zero and 0.05%

Variable	BAC zero Mean ± SD	BAC 0.05% Mean ± SD	Significance of differences (*P*)
Inspection time (IT)	73.0 ± 26.7	84.9 ± 23.4	<0.005
Simple RT (SRT)	246.1 ± 27.48	269.8 ± 47.2	<0.05
Complex RT (CRT)	643.0 ± 118.1	758.9 ± 190.8	<0.005
Picture completion (PC)	9.3 ± 0.9	7.9 ± 1.8	<0.005
Picture arrangement (PA)	7.6 ± 2.2	4.4 ± 2.4	<0.005
Object arrangement (OA)	85.00 ± 8.37	64.6 ± 25.9	<0.05
Block design (BD)	70.3 ± 19.3	67.8 ± 24.5	n.s.
Digit symbol (DS)	68.00 ± 14.2	64.7 ± 13.4	n.s.
Digit span forward (DF)	8.6 ± 1.7	8.1 ± 1.7	n.s.
Digit span backward (DB)	7.2 ± 2.0	6.6 ± 1.4	n.s.

n.s., not significant.

Impairment on IT as a predictor of impairment on total information processing (simple RT and complex RT and cognitive ability)

A linear regression was performed to assess whether IT accounted for the relationship between alcohol and simple and complex RT. This relationship was examined by using IT as a predictor variable in order to distinguish whether changes in performance on measures of total information processing still existed after taking into account the effects of alcohol on the early stages of information processing (IT). The results indicated that IT does not significantly contribute to the effect of alcohol on simple RT (t = –0.281, Sig T = 0.783) or complex RT (t = –1.162, Sig T = 0.265). An R^2 value of zero indicated that IT does not predict simple RT (R^2 = 0.006) or complex RT (R^2 = 0.088). There is no linear relationship between IT and simple RT [$F(1,14)$ = 0.079, P = 0.783] or complex RT [$F(1,14)$ = 1.35, P = 0.265], and there is no correlation between the predicted and observed values of simple (r = 0.075) or complex RT (r = 0.297). Hence, changes in simple and complex RT were not influenced by any changes in the early stages of information processing.

A linear multiple regression was also performed to assess whether IT accounted for the deleterious effects of alcohol on cognitive ability (PC, PA and OA of the WAIS-R). Results indicated that IT accounted for 2.7% of the variability in the effect of alcohol on PC (t = 2.31, Sig T < 0.05). A positive linear relationship between the effect of alcohol on IT and the effect of alcohol on PC was found [$F(1,14)$ = 5.33, P < 0.05], as was a correlation between the predicted and observed values of PC (r = 0.53). This suggests that impairment of the early stages of information processing influences the later stages of information processing that involve long-term memory, visual memory and attention to detail. On the other hand, the regression showed that IT does not significantly contribute to the effect of alcohol on PA (t = –0.30, Sig T = 0.77; R^2 = 0.006) or OA (t = 0.757, Sig T = 0.462; R^2 = 0.04). No linear relationship was found between IT and PA [$F(1,14)$ = 0.087, P = 0.772] or OA [$F(1,14)$ = 0.573, P = 0.462] and there was no significant correlation between the predicted and observed values of PA (r = 0.079) and OA (r = 0.198). This indicates that IT does not explain the deleterious effect of alcohol on PA and OA.

DISCUSSION

The present study supports previous research demonstrating that alcohol impairs information processing (Koelega, 1995). The results indicated that IT was impaired by alcohol administration, thus suggesting that alcohol slows the early stages of information processing that involve perceptual speed. In this case, the stimulus duration required to make a relatively simple response increased when BAC was 0.05%. The IT task has previously been shown to be sensitive to changes associated with pharmacological interventions (Stough *et al*., 1995), in which the ability to discriminate between different visual stimuli presented at different durations is critical. These results also support research that has examined the effects of alcohol on other tasks which assess the early stages of information processing, in which alcohol was found to impair performance on a visual tracking task (Maylor *et al*., 1990), and tasks that require the detection of small deviations (Jaaskelainen *et al*., 1995).

The present study found that alcohol administration impairs total information processing measured by simple RT, complex RT and cognitive ability. This finding is consistent with past research that has found alcohol to impair simple reflexes and to slow one's response to simple stimuli (Lemon *et al*., 1993), as well impair more complex responses (Maylor *et al*., 1990; Bartl *et al*., 1996).

Alcohol also impaired some aspects of cognitive ability. Results indicated that performance decreased on the PC, PA and OA subtests of the WAIS-R. These results support previous research reporting an impairment of higher-order cognitive functioning following alcohol administration (Koelega, 1995). Performance on the PC and PA subtests indicates that alcohol administration impairs one's ability to organize, visually represent and to make sense of visual information. Impairment on the PC subtest after alcohol indicates that the ability to draw information from long-term memory and visual information, as well as to focus attention to specific details, is impaired (Sprandel, 1995). These results are inconsistent with previous research that has shown low doses of alcohol to enhance attention to high-priority task components (Jubis, 1986). Performance on the PA subtest after alcohol administration indicated that alcohol impaired the synthesis of thought and processing of information that is required for abstract reasoning. As PA is regarded as measuring common sense and social intelligence, then logical reasoning, social skills and decision-making may also be impaired (Sprandel, 1995).

Performance on the OA subtest following alcohol administration indicated impaired visual motor coordination, where appropriate movements are required in order to respond to appropriate stimuli. These results are also inconsistent with previous research that has shown motor functions to be unaffected by alcohol (Kraepelin, 1892; Levine *et al*., 1975).

It is important to note that both simple and complex RT as well as some higher-order complex tasks from the WAIS-R were all impaired after alcohol administration, indicating that impairment from alcohol on simple decision-making is as significant as higher-order or complex decision-making. This obviously has important implications for understanding the behavioural impairment following alcohol on a range of social behaviours and cognitive functions such as driving.

Since this is the first study to examine the effects of alcohol on the WAIS-R subtests, it is difficult to compare these results to those obtained in other studies using different tasks. Further research examining the influence of alcohol on WAIS-R subtest performance is required to replicate the current results. Future research may wish to further disguise the alcohol condition by wiping alcohol on the glass in the placebo condition to further control for expectancy.

In conclusion, the present results show that alcohol impaired visual information processing, attention, abstract reasoning and visuo-motor coordination measured by the WAIS-R, and are consistent with the impairment observed on the IT, simple RT and complex RT. Results from the linear regression indicated that the effect of alcohol on IT did not predict the effect of alcohol on simple RT, complex RT or on the WAIS-R subtests (PA or OA). This suggests that the effect of alcohol on the early stages of information processing is not the cause of decreased performance in total information processing. Instead, the results indicate that all stages of information processing are impaired independently, consistent with the theory of impairment proposed by Post *et al*. (1996).

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