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Effects of ethanol and promethazine on awareness of errors and judgements of performance

Kim Acons *Department of Neuroscience, University of Edinburgh, UK.*
Li-san Chan *Department of Neuroscience, University of Edinburgh, UK.*
Gordon Drummond *Department of Anaesthesia, Pain, and Critical Care Medicine, University of Edinburgh, UK.*
Brian Tiplady *Department of Anaesthesia, Pain, and Critical Care Medicine, University of Edinburgh, UK.*

Abstract

Ethanol may affect detection and processing of errors in performance tasks, and thus influence the speed accuracy trade-off. In this double-blind study, 11 volunteers, (seven female, four male) took part in four sessions in which they received ethanol (Eth; mean blood alcohol concentration at 60 min: 87.3, SD: 18.4), placebo (Pla), promethazine 20 mg (P20) and 30 mg (P30) in randomized order. A computerized four choice reaction time test (FCRT), other performance measures and visual analogue scales (VAS) were administered before dosing and at intervals up to 2.5 h after. During the FCRT volunteers reported errors verbally. These reports were recorded together with error signals from the computer. The overall pattern of effects was as expected for Eth, with increases in errors for most tasks, and subjective drowsiness. P30 affected only the FCRT, and both P30 and P20 caused drowsiness. The number of errors made by the volunteers in the FCRT was significantly increased for both Eth ($N = 5.20$, $p < 0.01$) and P30 ($N = 3.81$, $p < 0.01$) compared to Pla (1.84) with no significant change in response speed. The proportion of errors detected was slightly but not significantly reduced (Pla 68%, Eth 63%, P30 57%). These results show that error processing is not significantly impaired by ethanol, and a reduction in awareness of errors cannot account for the increased errors which occur when performance is impaired by ethanol.

Keywords

ethanol, promethazine, speed–accuracy tradeoff, error detection

Introduction

Ethanol (alcohol) shows a characteristic pattern of impairment to psychomotor performance, with a substantial increase in errors or a reduction in accuracy, depending on the type of task, while speed of response is not greatly affected. This contrasts with many other types of CNS drugs, which slow performance more than ethanol, but have less effect on errors (Tiplady *et al.*, 2003). This contrast is illustrated for a tracking task and a choice reaction task using a speed–accuracy plot in Fig. 1. This type of plot is particularly useful for illustrating dissociations between the effects of different drugs. The double-dissociation between ethanol and temazepam is most marked for the maze task, where the effect of ethanol is almost entirely on errors, that of temazepam almost entirely on speed of performance. The dissociation is generally less clear-cut for reaction time tasks, with both drugs having some effect on both speed and accuracy. Nonetheless the difference between the two drugs is clearly seen, for example with the number–pairs task, a measure of attention in the presence of distractors (Fig. 1), and with several other reaction time tasks (Tiplady *et al.*, 1998, 1999).

Why should these drugs differ in the type of impairment they cause? When volunteers carry out psychomotor tasks they are typically instructed to 'work as fast and as accurately as you can' or 'go as fast as you can while trying not to make any mistakes'. Such instructions are ambiguous, since speed and accuracy can be traded off against each other. In these circumstances volunteers have to judge the relative importance of speed and accuracy, or what constitutes an 'acceptable' number of errors.

The balance between speed and accuracy adopted depends on factors such as personality (cautiousness or impulsivity), the setting of target or maximum times for responses, the instructions given to the volunteer concerning the relative importance of speed and accuracy, and feedback from the task (Wickelgren, 1977; Ridderinkhof, 2002). It is possible that drugs could affect the speed–accuracy trade-off, for example by influencing response

Corresponding author: Dr Brian Tiplady, 8 Braid Crescent, Edinburgh, EH10 6AU, UK. *Email*: brian@penscreen.com

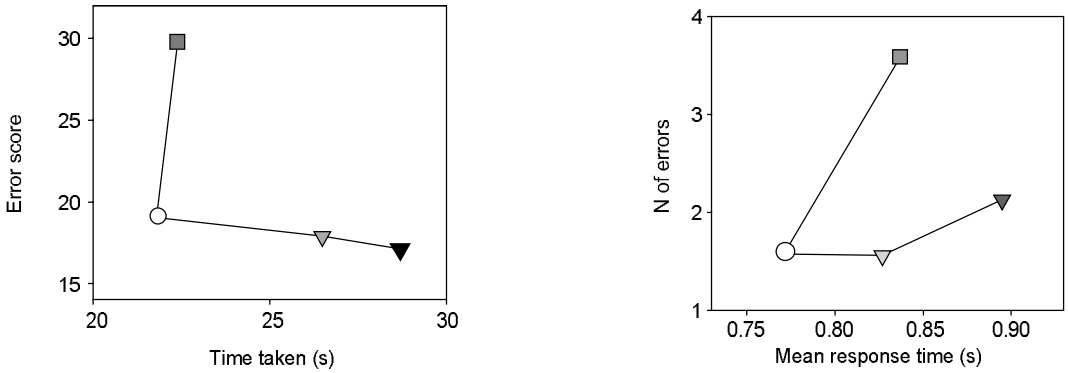

Figure 1 Effects of ethanol and temazepam on speed and accuracy of psychomotor performance (Tiplady *et al.*, 2003).

Left: spiral maze, a tracking task, in which volunteers follow a spiral path with a pen as quickly as possible, while staying within the path and avoiding obstacles. Right: number pairs, a row of five digits is displayed, and the task is to press a YES button if the second and fourth digits are the same, a NO button if not. Open circles, placebo; grey squares, ethanol, up to 0.8 g/kg; light grey triangle, temazepam 20 mg; dark grey triangle, temazepam 30 mg.

speed or willingness to respond (impulsivity). Another possibility is that drugs could affect the process by which errors are detected and responded to. Performance on a psychomotor task involves continuous monitoring of performance, with the volunteer setting the speed of performance on the basis of results (Rabbitt, 1979). As pointed out by Rabbitt, in order to maintain a stable balance between speed and accuracy, a person must be able both to detect errors when they occur and to monitor the speed of responses. Since errors occur relatively infrequently, the most likely pattern is that speed of responding is gradually increased until an error is made, and then responses are slowed in order to maintain performance at some 'optimal' level. This suggestion is supported by the observation that error responses are faster than correct responses, and those immediately after an error are slower than the mean response time in the task (Rabbitt, 1966; Smith and Brewer, 1995).

If the detection of errors is impaired, then this will affect task performance. If fewer errors are detected, the slowing in response to errors will occur less often. Responses will be faster overall, and more errors will be made. If the person has a well-defined and stable acceptable error rate, then the rate of *perceived* errors in the task should remain constant. Thus halving the error detection rate should lead to a doubling of the number of errors actually made.

There has been much recent interest in electrophysiological correlates of error processing, in particular error-related negativity (ERN). This event-related potential component occurs in situations such as erroneous responses, feedback concerning response accuracy, and after late responses in tasks with a deadline. ERN appears to be generated in the anterior cingulated cortex, an area involved with response conflict (for review, see Yeung *et al.*, 2004). ERN amplitude is reduced by drugs that impair performance on reaction time tasks including ethanol (Ridderinkhof *et al.*, 2002) and benzodiazepines (Johannes *et al.*, 2001; de Bruijn *et al.*, 2004). No direct comparison has been made between the two classes of drugs, so the pharmacological specificity of this effect is not clear. Electrophysiological and functional imaging data show that error detection is a distinct process that is associated with activation of different cortical areas from those involved with related functions such as inhibition and error correction (Garavan *et al.*, 2002).

It is therefore of interest to investigate the effects of impairing drugs such as ethanol on error detection. Participants in simple reaction time experiments are clearly aware of their errors, and can report or correct them with high probability. Much previous work in this area has used error correction as the main measure (see e.g. Rabbitt, 1968, 2002). This has the advantage of being a natural and straightforward way for a volunteer to react. However in view of the suggestion that error detection and correction are distinct processes, and that less work has been done on error detection, we have concentrated on the earlier stage of error detection. Rabbitt (2002) has used a second button push after the initial response as a signal that an error has been spotted, but this has the disadvantage that it breaks the rhythm of task performance, and may significantly change the nature of the task. In this study we used a verbal response to errors in a four-choice serial reaction time task. No feedback to errors was given, and erroneous responses were not to be corrected. We have previously shown that ethanol affects both speed and accuracy on this four-choice task (Tiplady *et al.*, 1998, 2001).

Our primary hypothesis was that error detection would be reduced by ethanol. We predicted that the reduction would match the increase in errors with ethanol, so that the number of errors actually detected would remain constant. We included other performance tests to assess the pattern of changes due to the drug, and assessed volunteers' view of their own performance at the end of each session. We compared the effects of ethanol and promethazine, a centrally active antihistamine, with placebo. Promethazine was chosen as a comparator as it represents a class of sedative agents which have not previously been used in this type of comparison.

Methods

Design

We used a double-blind within-subjects design, comparing single doses of (1) ethanol, calculated to produce peak plasma ethanol concentrations in the range 80–100 mg/100 ml, (2) placebo, (3) promethazine 20 mg, (4) promethazine 30 mg. Doses were given on separate days at least 4 days apart. The order of administration was randomized using latin squares.

Volunteers

Eleven volunteers, seven female and four male, aged 18–24 years (mean 21.3) and weighing 54–121 kg (mean 71.2 kg) took part. All were healthy as assessed at initial screening, were light to moderate social drinkers (reported consumption 5–30 units ethanol/week, mean 16.6), had negative pregnancy tests if female and were not taking any medication that might have interfered with CNS function or drug absorption or elimination. Volunteers gave written informed consent to participate in the study, which was approved by the research ethics committee of the Lothian Health Board.

Assessments

The following tests were used:

Four-choice reaction task (Tiplady et al., 2001) Four stimulus locations were arranged in a square pattern on the computer screen, and a response box had four corresponding buttons. Stimulus locations were illuminated one at a time in pseudorandom order. The volunteer was instructed to press the appropriate button as quickly as possible. The next stimulus appeared immediately after the button press. No feedback was given to incorrect responses. Volunteers were instructed to give a monosyllabic verbal response each time they realized they had made an error, but not to make any attempt to correct the error. Response times and correct and incorrect responses were recorded. The error responses were recorded with a microphone which fed into one track of a stereo audio recorder. Signals from the computer indicating that an error had occurred (inaudible to the volunteer) were fed into the other channel. The recording was subsequently played back and scored to give measures of correct and incorrect error detection.

Performance questionnaire Immediately after completing the four-choice reaction time task, volunteers were asked to assess their performance on the task. The questionnaire consisted of three questions concerning speed, accuracy and overall performance rated on Visual Analogue Scales

Spiral maze (Gibson, 1978) This paper and pencil maze consisted of a white path bounded by a black spiral, with circular obstacles. The pencil was placed at the centre of the spiral and the path traced around the spiral as rapidly as possible while avoiding the black sides and the obstacles. Time taken was recorded with a stopwatch. and the error score obtained by marking one point if the line touched an obstacle or the side of the track, two points if it penetrated.

Zig-zag tracking This tracking task consisted of a grey zig-zag track with circular obstacles. The volunteer followed the grey track with a pen as rapidly as possible while trying to avoid the obstacles. The task was scored in the same way as the spiral maze. Both the spiral maze and zig-zag tracking assess psychomotor speed and accuracy.

Digit-symbol substitution In this pencil and paper task there was a key which matched nine symbols to the digits 1–9. Below this there was a series of random digits with a box beneath each digit in which the volunteer wrote the corresponding symbol as quickly as possible. The number of digits correctly substituted in 90 s and the number of errors were recorded (Wechsler, 1958). This task assesses speed of cognitive processing.

Arrow flanker task Sets of five symbols appeared on the computer screen one set at a time. The central symbol (target) was always an arrow, pointing either to the right or the left. The other four symbols (flankers) were either congruent (arrows pointing in the same direction as the target), incongruent (arrows pointing in the opposite direction to the target), neutral (squares) or suppressors (crosses). All four flanker symbols were always the same in a given stimulus. The task was to tap a left or right button corresponding to the direction of the central target arrow as quickly as possible, unless the flankers were crosses, in which case no response was to be made. The task was derived from the flanker paradigm described by Eriksen and Eriksen (1974). This task assesses ability to focus attention in the presence of distracting information.

Logical reasoning/working memory (Kyllonen, personal communication) A set of three rules appeared one after the other on the computer screen, each being shown for 3 seconds, for example 'The dog comes before the pig', 'The chair does not come after the table', 'The furniture comes after the animals'. A set of eight response choices then appeared, from which the volunteer tapped on the correct one, in this case 'Dog – Pig – Chair – Table'. Twenty four problems were presented, and the total number of correct responses recorded. This task assesses working memory, i.e. the ability to hold information in memory while processing it (Baddeley, 1996).

Selective reminding (Buschke and Fuld, 1974) The experimenter read a list of 15 words to the volunteer, who then recalled as many words as possible in any order. The experimenter then read out those words not recalled on the first occasion, and the volunteer again attempted to recall the entire list. This procedure was repeated six times. A measure of recall from long-term memory was obtained. This task assesses the ability to form new long-term episodic memory.

Visual analogue scales (Cameron et al., 2001) Twenty-four scales, including the 16 described by Bond and Lader (1974) were

used to assess mood. Each scale consisted of a 10 cm line presented on the computer screen, the ends of which were marked with antonyms (e.g. alert–drowsy). Volunteers made a mark on each line to indicate how they felt at that moment.

Equipment

The four-choice reaction time task was carried out on a BBC Micro Model B Computer equipped with a custom response box as previously described (Tiplady, 1985; Cameron *et al.*, 2001). The arrow flanker task was presented using a Nokia 6610 mobile phone (Tiplady, 2004). The logical memory task and visual analogue scales used an Apple MessagePad pen computer (Cameron *et al.*, 2001). Other tasks were administered by the experimenters using pen and paper.

Blood alcohol concentrations were estimated from breath using a Lion Alcolmeter model S-D2 (Lion Laboratories, Barry, South Glamorgan, UK).

Procedures

Each volunteer first took part in a practice session in which all tests were demonstrated and practised twice with the exception of selective reminding, which was carried out once.

In each of the four main drug sessions, a baseline test administration was first carried out. The volunteer was then given a capsule containing either 20 or 30 mg promethazine or lactose (placebo), and a drink containing either vodka or water (placebo) mixed with an equal volume of orange drink concentrate. The volume was calculated to give a dose of 0.8 g/kg body weight for males, up to a maximum of 66 g (200 ml of 37.5% vodka) or 0.7 g/kg for females up to a maximum of 55 g (167 ml). To mask the taste of vodka, the drink was sprayed with peppermint breath freshener, and the volunteer sucked a Tyrozet® lozenge (containing the local anaesthetic benzocaine) for 1 min before consuming the drink.

The test battery was then administered beginning at 30, 75 and 135 min after the start of the drink. The test battery consisted of all the tests listed above except for selective reminding, which was only given once, in the 75 min battery. Breathalyser readings were taken at the beginning and end of each test battery administration.

Volunteers were instructed to refrain from eating for 4 hours before each session, and to eat only light meals before that time. A maximum of one cup of tea or coffee was to be drunk at breakfast time, to be the same on each test day. No further caffeine was permitted until the completion of all test procedures. They were instructed not to consume any alcohol from 24 h before the start of the test session until at least 24 h after, or any tobacco from 2 h before the start of the session until the completion of all test procedures.

Statistical analysis

For each test measure in the main battery, the mean of the three post-treatment values was first obtained. This mean was then analysed using an analysis of covariance (PROC GLM in SAS statistical software package) with the pre-treatment (baseline) value as a covariate. If an overall statistically significant effect of treatment was found ($p < 0.05$), pairwise comparisons were carried out using t-tests.

Scores from the visual analogue scales were combined into two factors, (I) functional integrity (drowsy, feeble, muzzy, clumsy, lethargic, mentally slow, dreamy, incompetent, bored) and (II) mood (excited, discontented, troubled, tense, sad, antagonistic, unsociable) as previously described (Cameron *et al.*, 2001), before being analysed as above. In addition the sober–drunk, alert–drowsy and normal–abnormal scales were analysed individually.

Scores from the individual time points for the error score from the four-choice reaction time task and for the functional integrity factor from the visual analogue scales were analysed using analysis of covariance with baseline score as a covariate.

For the selective reminding task only a single post-treatment value was obtained, at 90 min after the dose, and this was analysed using analysis of variance.

Results

The blood alcohol concentrations during the ethanol sessions are shown in Fig. 2. Peak levels slightly above 80 mg/100 ml (the UK legal limit for driving) were obtained, as intended.

Results from the performance tests and mood scales are presented in Table 1. The four-choice test showed significant increases in errors for ethanol and for the high dose of promethazine, with no significant effect on response speed for either drug. Digit-symbol substitution showed a decrease in correct substitutions with ethanol but not with promethazine. Both the tracking tasks (spiral maze and zig-zag tracking) showed increases in error scores for ethanol, with no effect on speed, and no significant

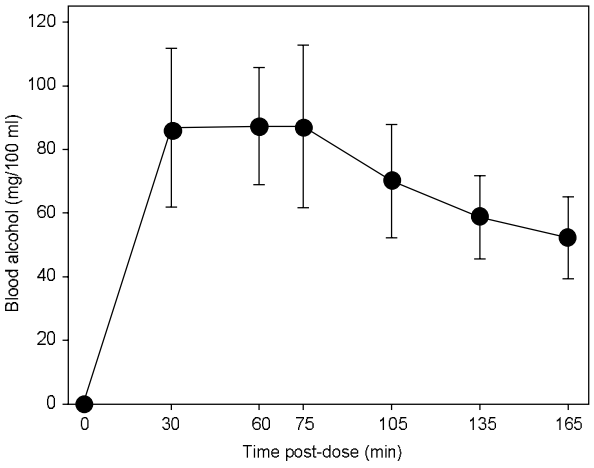

Figure 2 Mean blood alcohol concentrations during the ethanol sessions. Error bars indicate standard deviations.

Table 1 Data for performance tests and mood ratings

Test/measure	Placebo	Ethanol	Promethazine 20 mg	Promethazine 30 mg	S.E.	Treatment effect $p =$
Four-choice reaction time						
Mean reaction time (ms)	313.3	302.2	300.4	298.1	11.17	0.496
Total N of errors	1.84	5.20***	2.61	3.81**	0.70	0.0003
Digit-symbol						
N correct	80.5	73.4***	78.4	78.5	1.33	0.0001
N incorrect	0.378	0.066	0.061	0.223	0.26	0.568
Logical working memory						
N correct	21.6	19.6	20.6	20.8	0.75	0.0955
Spiral maze						
Error score	4.67	7.79**	6.10	6.26	0.99	0.0346
Total time(s)	31.5	31.4	31.3	30.5	0.82	0.474
Zig-zag tracking						
Error score	12.2	20.1***	14.5	13.4	1.51	0.0001
Total time(s)	52.4	55.2	53.9	54.3	1.71	0.440
Arrow flankers						
Overall reaction time	0.653	0.681	0.678	0.689	0.016	0.145
Errors	11.7	14.6	11.2	10.5	3.24	0.624
False positives	46.9	65.7	61.7	62.5	25.97	0.889
Information transfer	1.43	1.35	1.38	1.36	0.03	0.143
Selective reminding						
Long-term recall (max 90)	77.3	66.4	73.05	73.88	3.99	0.0721
Visual analogue scales (mm)						
Factor I	25.2	41.0***	31.1*	32.4*	2.71	0.0000
Factor II	22.2	22.8	22.9	23.1	1.73	0.938
Drowsy	25.2	42.8***	32.1	34.8*	4.31	0.0035
Drunk	6.4	48.8***	8.0	9.2	4.92	0.0000
Abnormal	12.0	24.1***	18.4**	18.7**	2.42	0.0002

Key: SE, Standard Error; *$p<0.05$, **$p<0.01$, ***$p<0.001$.

effect for either dose of promethazine. Logical working memory, arrow flankers and selective reminding showed no significant drug effects, though all three tests showed trends towards impairment in the drug conditions. Visual analogue scales showed increases in scores on factor I, 'functional impairment', with all drug conditions, while no changes were found on factor II, 'mood'. Scores from individual scales showed that ethanol but not promethazine produced feelings of drunkenness, that ethanol and the larger dose of promethazine produced drowsiness, and that all drug conditions led to feelings of abnormality.

Fig. 3 shows the time course of drug effects for the error score from the four-choice reaction time task and for the functional integrity scale. Significant differences from placebo were found for ethanol at all time-points for both measures, for promethazine 30 mg for all time-points for both measures except for the error score at 90 min post-dose and for 20 mg promethazine for the functional integrity scale at 90 min.

Error detection results are shown in Fig. 4. As already seen, the number of errors made in the four-choice task increased with ethanol and with the larger dose of promethazine, the ratios between errors on drug and placebo being 2.9 ($p<0.001$) and 2.1 ($p<0.01$) respectively. No significant changes were found in the proportion of errors detected for any drug condition (Pla, 68%; Eth, 63%; P30, 57%; $p=0.475$).

Ratings by volunteers of their performance in the four-choice test made at the end of the test are shown in Fig. 5. Ratings of overall performance were significantly less for ethanol ($p<0.001$) and for the larger dose of promethazine ($p<0.05$). No significant changes were found in ratings for speed. Ratings for accuracy of performance were significantly less with ethanol. No significant changes were seen in the ratings volunteers made of the proportion of errors they detected in any drug condition.

Discussion

The pattern of results for performance and mood ratings with ethanol was broadly as expected. The maximum blood alcohol concentration obtained was close to the legal limit, as intended. For the tests which showed significant effects of ethanol, the

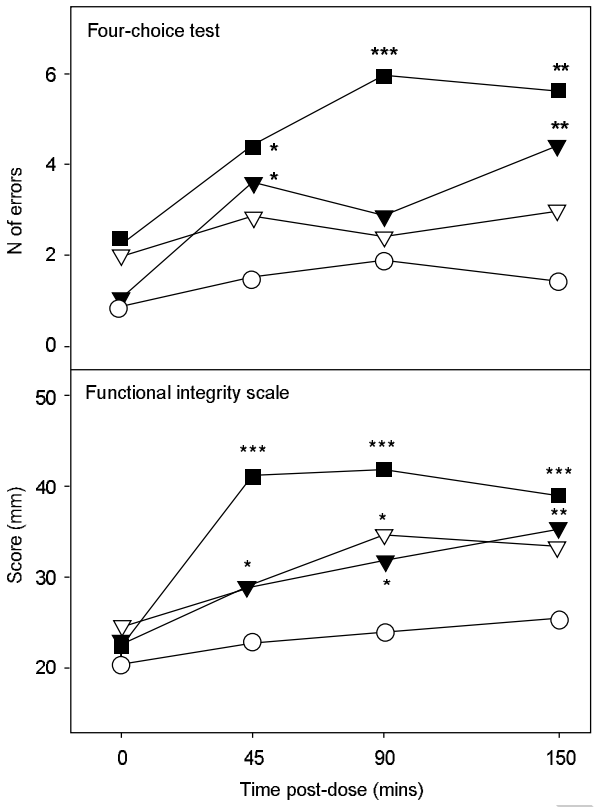

Figure 3 Time course of effects of ethanol on performance and mood.

Top: error score on the four-choice reaction time task. Bottom: scores on factor I (functional integrity) derived from the visual analogue scales. Open circles, placebo; open triangles, promethazine 20 mg; Filled triangles: promethazine 30 mg; filled squares, ethanol. Stars indicate significance of differences from placebo: $*p<0.05$, $**p<0.01$, $***p<0.001$.

changes were principally in the error or accuracy components of the tests, with smaller or no effect on the speed component, as has been previously reported (Tiplady, 1998, 2003). For those tests which did not show statistical significance, changes were in the expected direction. Ethanol led to feelings of drunkenness, and to a lesser extent to feelings of drowsiness.

The sedative effects of promethazine were clearly seen in the results from the mood scales, with significant subjective drowsiness and feelings of impairment. Of the objective test measures, only the error score on the four-choice test showed significance, although several other tests showed trends towards impairment. The time-course of action of the two drugs was different (Fig. 3). Peak effects of ethanol were seen at the 90 min time-point. For the larger dose of promethazine, peak effects were seen at 150 min. For logistical reasons, the test sessions were limited to 3 hours. This was not sufficient to follow promethazine effects past the peak. Previous work has suggested that maximum effects of promethazine are seen at about 3 h after oral dosing (see e.g. Hindmarch *et al.*, 2001), so the final time-point in this study should be close to the peak effect of promethazine. The fact that significant effects of 30 mg promethazine on both objective and subjective measures were seen starting with the first (45 min) time-point justifies the use of the mean of the three post-dose assessments as a summary measure to compare the two drugs.

Promethazine 30 mg had much less objective and subjective effects than ethanol. Although the sedative effects of promethazine are well established (see e.g. Parrott and Wesnes, 1987; Hindmarch *et al.*, 2001), no previous study has directly compared this antihistamine with ethanol. One indirect comparison suggested that promethazine 25 mg i.m. had comparable effects on performance to ethanol at a blood alcohol concentration of 85 mg/100 ml. However, the different routes of administration make these comparisons difficult to assess.

We found little effect of any drug condition on the proportion of errors correctly detected (Fig. 4). There was a slight trend towards lower detection with ethanol and the larger dose of promethazine, but this was not significant. From the ratings made at the end of each test (Fig. 5) it is clear that volunteers appreciated their own performance in all drug conditions. Volunteers reported poorer overall performance, and poorer avoidance of errors, with no significant change reported for speed. The reported reductions were greatest for ethanol and less for promethazine, thus corresponding to the objective impairments found. The only apparent discrepancy was in the proportion of errors volunteers thought they had detected, which was greater for all drug conditions than placebo, the opposite of the actual pattern of detection. However neither objective nor subjective measures showed significant differences for this aspect of performance.

These results contrast with previous findings using a general knowledge task, where ethanol increased confidence in task performance (Tiplady *et al.*, 2004). It may be that perception of impairment depends on the type of task that is involved. The four-choice task involves a very simple discrimination. By contrast, in the general knowledge task volunteers may believe that they have given a correct response when they have made an error, or be unsure, guess, and give themselves the benefit of the doubt.

The error rates for the four-choice task are relatively low, involving about 0.7% of responses for placebo and 2% of responses for ethanol. Nonetheless, volunteers impaired by ethanol know that they are making errors during the test; they remember those errors at the end of the test and they correctly assess that their performance impairment took the form of increased errors, not of reduced speed. Thus both error detection and memory for errors are essentially normal in the ethanol condition, in contradiction to the study hypothesis. All volunteers made some errors, and the increase in errors with ethanol was nearly threefold, while speed was if anything slightly increased. The discrimination in this test is a simple one, and any error rate down to near zero can be easily achieved if enough time is taken, so volunteers are in effect accepting this very substantial increase in the error rate. Why do they do so?

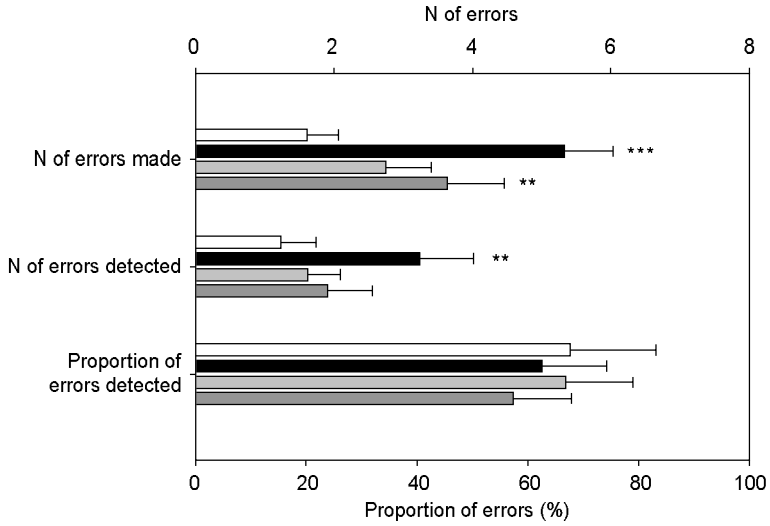

Figure 4 Error detection in the four-choice reaction time task.

Top: total number of errors made during the task; centre: total number of errors correctly detected during the task; bottom: proportion of errors correctly detected. White, placebo; black, ethanol; light grey, promethazine 20 mg; dark grey, promethazine 30 mg. Error bars indicate the standard error of the mean. $^{**}p < 0.01$, $^{***}p < 0.001$ compared to placebo.

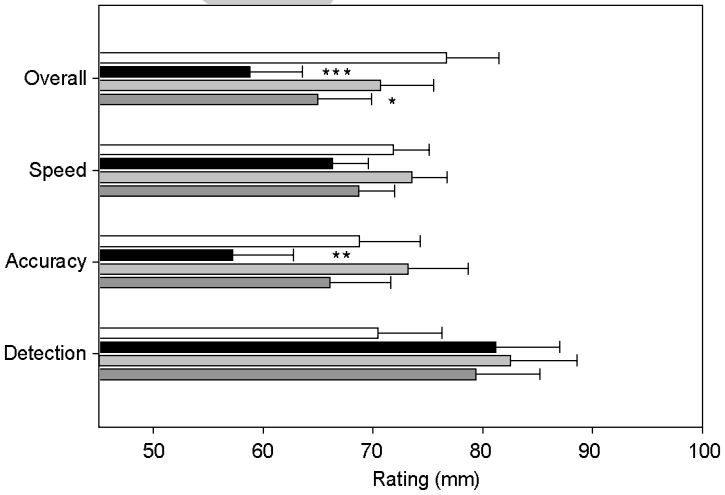

Figure 5 Performance ratings in the four-choice reaction time task.

Question texts were: overall, 'How well do you think you did in the test *overall*?'; speed, 'How well do you think you did for *speed*?';. accuracy, 'How well do you think you did with avoiding *errors*?', detection, 'What *proportion* of the errors do you think you spotted in the test?'; white, placebo; black, ethanol; light grey, promethazine 20 mg; dark grey, promethazine 30 mg. Error bars indicate the standard error of the mean. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$ compared to placebo.

Steele and Josephs (1990) suggest that many of the effects of ethanol may be understood in terms of 'alcohol myopia'. This proposes that processing capacity is reduced by ethanol, and the response is to focus attention on the most salient aspects of the situation, while neglecting or giving less attention to other aspects. An example that fits this account is the work of Billings *et al.* (1973) on actual flying performance at ethanol blood concentrations of 40, 80 and 120 mg/100 ml. Handling of the plane (tracking performance) was not affected at the lowest dose, but showed a rapidly increasing impairment as dose increased. Errors, on the other hand, showed a linear increase with dose, being significantly affected at the lowest dose. Thus flying the plane is here the most salient task, and will be concentrated on at the expense of other activities at moderate levels of impairment. At higher levels, all aspects of performance suffer. More recent work using simulators has found similar results (for review, see Cook, 1997, especially p. 543).

In the context of a reaction time task, speed may be considered the most salient aspect of performance, since it is involved in every response. Errors occur in only a few per cent of responses. While errors may be very important in real-life tasks, the relative infrequency of their occurrence may lead to them being seen as less salient, and so more susceptible to impairment by ethanol. Tiplady *et al.* (2001) tested this model by attempting to make errors more salient to volunteers using instructions that emphasized either speed or accuracy. The instructions affected the

speed–accuracy trade-off, but the relative effect of ethanol on speed and accuracy was not affected. This argues against the salience interpretation, though other ways of affecting the trade-off, such as feedback or payment, might have a greater effect than instructions.

The concept of impulsivity is also relevant here. Much work has focused on errors of commission. These typically occur in the type of attention task where a response is made if a specified stimulus is present and no response is to be made otherwise. Commission errors in this type of task are more frequent in clinical conditions associated with impulsive behaviour, and are also increased by ethanol (Finn *et al.*, 1999; Dougherty *et al.*, 1999, 2000). With serial response tasks, such as the four-choice task used here, responses are made to every stimulus. Thus errors of commission are not a separate category for this type of task. However, a variant of this model (the deadline model) can be applied in which accurate decision making requires a certain processing time, and impulsive responses are considered to be those which are made before this process has been completed (Ollman, 1966; Yellot, 1971; Rinkenauer *et al.*, 2004). With this model it is the time taken to complete processing which is likely to be affected by drugs, and the error rate is secondary to this. Whether ethanol might have specific effects on speed of response, independent of errors, is an important question that has not been directly addressed.

Although there are results from ethanol which are relevant to both these models, and there have also been some studies with stimulants and impulsivity, no comparisons of ethanol with other impairing drugs have been made. This is a general limitation of the ethanol literature. Many studies demonstrate interesting findings that may contribute to an understanding of the special problems that ethanol causes, but unless the pharmacological specificity of the effects are studied, these effects cannot be properly evaluated (Tiplady *et al.*, 1998, 1999). In the present study the value of the comparison we used was limited by the modest effect actually observed with promethazine, but this does not invalidate the principle of establishing pharmacological specificity. Further work on errors should compare ethanol with other impairing drugs assessing salience and impulsivity models.

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