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ORIGINAL INVESTIGATION

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Acute effects of alcohol on divided and covert attention in men

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Abstract *Rationale:* While several studies identified divided attention to be sensitive to alcohol effects, the impact of alcohol on covert visual attention is still not clear, despite the latter's important role in perception. *Objectives:* The study tests the effect of acute moderate doses of alcohol on divided and covert attention in right-handed, male volunteers. *Methods:* The design of the study involved a double-blind trial with an alcohol and a placebo condition; measurements were taken before and after an oral dose of 0.6 g/kg alcohol versus placebo. In the divided-attention task, simultaneous visuo-spatial and auditory stimulation was applied. In a test of covert attention, subjects had to shift their attentional focus according to a central cue, from one location in the visual field to another. *Results:* Under the divided-attention condition, reaction times were significantly prolonged after alcohol ingestion compared to placebo. Covert attention pre-post change was also significantly different between the alcohol and placebo groups. There is a reduction of false-cueing disturbance for left-appearing stimuli under moderate alcohol but an increase of disturbance for rightward stimuli, i.e. we found a lateralised pattern of reaction for spatial orienting. In the placebo group, no significant differences in right-left performance were obtained. *Conclusion:* The results suggest that sensory-attentional mechanisms play a key role in altered visual perceptual performance after alcohol ingestion. Furthermore, differences between the right and left visual field in the cued target-detection task indicate that alcohol exerts an influence on right-hemispheric attentional priming.

Keywords Alcohol · Covert attention · Divided attention · Lateralisation

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Introduction

Even though every-day experience alerts us to the detrimental effect of alcohol on attention, the precise effect is puzzling. Results from scientific experiments suggest different effects depending upon the subtype of attention (Koelega 1995). It is well known that divided-attention tasks are highly sensitive to the effects of alcohol (Landauer and Howat 1983; Moskowitz and Robinson 1987; Roehrs et al. 1994). A deterioration in performance is seen when two tasks are performed together, compared to when they are performed singly (Perry and Hodges 1999). Road accident data suggest a close relationship between alcohol and attention performance (Buser et al. 1996; Voas et al. 2000). Johnson (1982) proposes a link between alcohol-related crashes in curves during automobile driving and divided attention. In contrast, Linnoila (1974) and Fagan et al. (1987) report that alcohol does not affect vigilance, described as a state of readiness to detect and respond to unpredictable and rare events (Broadbent 1971). Similarly, Miles et al. (1986) note that sustained attention tasks, defined as maintaining attention to a single source of information for an unbroken period of time (Parasuraman and Davies 1984), have consistently failed to reveal alcohol-induced impairments, whereas tasks requiring selective attention, defined as attending to one source of information and excluding another, do reveal such impairments. It is possible that divided attention tasks in general are more sensitive than vigilance tasks, but there may be some types of vigilance task that do show alcohol effects (Miles et al. 1986; Rohrbaugh et

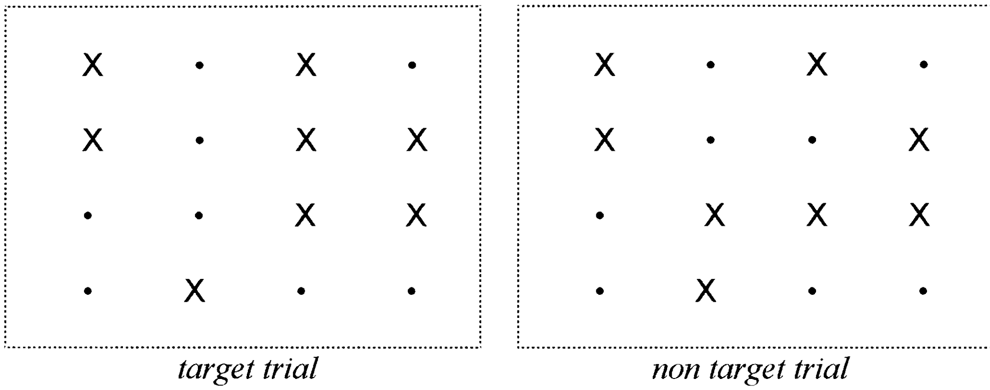

Fig. 1 The visual task was to detect a square pattern, formed by four out of eight crosses presented on the computer screen (see the four neighboring *X* in the target trial). All crosses constantly changed their location within a grid of four by four positions

al. 1988; Horne and Gibbons 1991). From these studies it seems that for studying the effects of alcohol it is useful to draw a distinction between (i) global aspects of attention, such as arousal or vigilance, (ii) sensory attention or selective attention and in particular spatial attention (Post et al. 1996), and (iii) the ability to divide attention between different sensory modalities (Maylor et al. 1990; Braun 1999).

To emphasise the difference between a shift of spatial attention by eye movements versus internal movement of a focus of attention (the so-called spotlight of attention), Posner (1980) has coined the distinction between overt and covert attention. Covert attention has been mostly investigated using location-cueing tasks, in which a spatial cue presented in advance of the target directs the participant's attention to a location while fixation remains steady at another location. The impact of alcohol on covert attention has still not been studied, despite the concept's important role in visual perception (Heinze et al. 1994; Desimone and Duncan 1995; Woldorff et al. 1999).

To understand how alcohol influences attentional processes, it is of interest to determine the brain structures involved in this process. Ethanol may potentiate the action of endogenous GABA by increasing the sensitivity of a specific $GABA_A$ receptor subunit. Frye and Breese (1982) demonstrated that GABA agonists can enhance ethanol-induced sedation. Robinson and Petersen (1992) showed effects of chemically induced unilateral deactivation of the pulvinar dorsomedial region (PDM) on spatial cueing task in monkeys. When muscimol, a GABA agonist, was injected in that region of the thalamus, the monkey had difficulties shifting its attention to the contralateral visual field. In contrast, when bicuculine, a GABA antagonist, was injected, the monkey could shift its attention more easily to the contralateral visual field. The allocation of spatial attention is further controlled by parietal brain structures (Posner et al. 1984; Rafal and Posner 1987; Cohen et al. 1994). Specifically, there is considerable evidence for a predominance of the right hemisphere for this attentional shift (Ladavas et al. 1989). In an fMRI study, Levin et al. (1998) showed that the right hemispheric predominance of activation in response to visual stimulation by a diffuse flash was reduced following alcohol.

The purpose of the present study was to evaluate the influence of acute, moderate alcohol consumption on attentional performance using tasks of divided attention and covert shift of attention. From previous work, the divided-attention task would be expected to be sensitive to alcohol consumption. Our present interest was therefore to determine whether this would also be the case with moderate doses. The effects of alcohol on covert shift of attention have not been previously studied.

Materials and methods

We studied 46 right-handed male volunteers (mean age 28.5±3.94 years). Subjects were recruited via newspaper advertisements and were paid for their participation. All were healthy as shown by physical examination and none had a history of alcohol or drug abuse. Prior to being accepted, potential volunteers completed a questionnaire on their habits of alcohol consumption and biological markers of consumption were measured. Written informed consent was obtained from all participants and the study was approved by the local ethics committee. Subjects were instructed to stay abstinent from alcohol for 1 day before testing. The experiment was performed at the same time of day for each subject and at least 2 h after the last meal, to minimise the effect of circadian cycle on cognitive performance (Babkoff et al. 1991).

Assessment instruments

Two different types of attention were measured with computerised standardised attention tasks (TAP, Test battery of attention; Zimmermann and Fimm 1994). Subjects were seated in a darkened room in front of a 14" computer screen at a viewing distance of 60–70 cm.

The divided attention task measures the ability to divide attention between two sensory modalities (dual task performance), here visuo-spatial and auditory stimulation. The visual task was to detect a square pattern, consisting of four out of eight crosses presented on the computer screen. All crosses constantly changed their location within a grid of four by four positions (see Fig. 1). In the auditory task, two tones alternated, and the subject had to detect irregularities in this two-tone sequence. To ensure correct single task performance, subjects had to perform a probe trial for each task. In the following test, 100 visual and 200 auditory stimuli were presented simultaneously. Reaction times, misses, anticipations and false positives were recorded.

In the covert shift of attention task (Posner 1980), subjects had to shift their attentional focus according to a cue that appeared before each stimulus presentation. Maintaining fixation to a central fixation cross was controlled visually by the experimenter who,

Table 1 Baseline characteristics of the subject groups. *BMI* Body-mass index; the d2 (Brickenkamp 1994) was used to assess the capacity for concentration and the number of correctly identified elements (*GZ-F*); *Drinks/w* drinks per week; biological markers (normal range in parentheses): *CDT* carbohydrate-deficient transferrin; *MCV* mean corpuscular volume; *GGT* gamma glutamyl transferase. Significance level is at $P<0.05$

	Alcohol group (*n*=23)	Placebo group (*n*=23)	*t*-Test
Age, years	28.8±4.3	28.1±3.5	n.s.
BMI, kg/m^2	23.4±3.3	23.5±5.9	n.s.
d2, GZ-F	474±65	469±74	n.s.
Drinks/w	5±6	7±7	n.s.
Smoker/nonsmoker	9 (39%)/14 (61%)	6 (26%)/17 (74%)	n.s. (χ^2)
CDT (<6%)	3.37±0.9	3.34±1	n.s.
MCV (80–95 fl)	88.22±3.3	89.83±4.4	n.s.
GGT (<0.82 µmol/s.l)	0.43±0.32	0.37±0.29	n.s.

Table 2 Results of divided-attention task (error rate and reaction time (*RT*); group means of median and SEM). Statistical test: Mann-Whitney *U*-test

Divided attention Pre-post difference		Alcohol group (*n*=23)		Placebo group (*n*=23)		Alcohol minus placebo	*U*-test	
			Δ Pre-post		Δ Pre-post		*z*	*P*
Error rate	Pre	1.39±0.28	0.48±0.26	2.17±0.42	–0.13±0.48	–0.61±0.48	–2.21	0.03
	Post	1.87±0.34		2.04±0.60				
Auditory RT (ms)	Pre	576.3±13.7	–5.8±8.3	581.8±15.4	–35.6±12.2	–29.8±14.7	–1.92	0.06
	Post	570.5±16.4		546.2±13.6				
Visual RT (ms)	Pre	799.2±19.7	41.6±18.8	799.5±18.8	1.1±16.8	–40.5±25.2	–1.24	0.21
	Post	840.8±26.3		800.6±20.1				
Total RT (ms)	Pre	672.0±12.6	17.3±11.3	689.6±15.2	–18.4±10.2	–35.7±15.2	–2.52	0.01
	Post	689.3±16.7		671.2±10.5				

online, excluded trials contaminated by eye movements. The attentional shift was manipulated by a central arrow cue which, in the cue-valid cases, indicated the position (left or right) of the target stimulus. In 20% of the trials, the target appeared at the opposite, unattended side (cue-invalid cases). The subject was asked to react, as fast as possible, by pressing a button upon appearance of the target stimulus. Normally, the reaction time to a visual target is faster when attention is shifted to the location of the target by valid cue compared to when the cue misdirects attention (invalid cue). The difference in reaction time between valid and invalid cue conditions is referred to as the validity effect, an index of costs and benefits of spatial orienting (Posner 1980; Davidson et al. 1999).

Procedure

In order to familiarise all subjects with the attention tasks, 1 week before the start of the experiment baseline measurements were obtained with the computer-based standardised attention test battery. The design of the study involved a double-blind trial with an alcohol and a placebo condition. Measurements were performed before and after an oral dose of 0.6 g/kg alcohol (a mix of vodka and orange juice) versus placebo (orange juice with 2 ml of vodka floated on the top). Blood alcohol level (BAL) was continuously assessed using a breath-alcohol analyser (AlcoQuant A 3020, EnviteC-Wismar) and venous blood samples. Post-alcohol recording started after BAL had exceeded the maximum of the individual alcohol curve, i.e., when there was no further increase for four consecutive measurements. This peak was reached after approximately 30 min. All subjects were examined following the same time schedule starting at 11 a.m. A first venous blood sample was taken at 11 a.m., followed by questionnaires and a standard meal. At 1 p.m., the pre-alcohol assessment started. Alcohol intake took place at 2 p.m., the second blood sample was taken at 2.30 p.m. At 2.40 p.m. the post-alcohol assessment was carried out. One experimenter prepared and handed out the drinks and also took the blood-alcohol readings. The experiment was double-blind because neither the experimenter, who conducted the attention tests, nor the subjects were informed about the mixture of the drink.

Statistical analysis

Non-parametric statistics were used (since raw RTs are not normally distributed and there are only 23 subjects per group). The results of the divided-attention task were analysed using the Mann-Whitney *U*-test and of the covert shift-of-attention task by the Wilcoxon test. To explore interaction effects an ANOVA was additionally applied. The alpha level was set to 0.05 for all statistical tests (two-tailed) (statistical software: SPSS 8.0).

Results

The alcohol and the placebo groups were well matched, as seen in Table 1, being not statistically different in age, body mass index (BMI), initial performance in a well-established paper-pencil test of selective attention (d2-test; Brickenkamp 1994), or in the amount of alcohol or cigarette consumption. Moreover, the two groups did not differ in the blood alcohol markers CDT (carbohydrate deficient transferrin), MCV (mean corpuscular volume) and GGT (gamma glutamyl transferase). The mean breath alcohol concentration was 0.05% at its peak; the blood alcohol level as determined from the venous samples was slightly higher (0.06% BAC).

The task of divided attention after alcohol ingestion in comparison to placebo revealed significant effects both

Table 3 Influence of alcohol on the cue-validity effect in the visuo-spatial attention task (Posner paradigm). Reaction times (*RT*) for valid and invalid cue condition (group means of median and SEM) and the validity effect (invalid-cue minus valid-cue RT). Test of mean differences by the Wilcoxon test

Covert attention	Alcohol group (*n*=23)			Placebo group (*n*=23)		
Pre		*z*	*P*		*z*	*P*
Valid cue RT (ms)	293±12.1	–4.167	0.0001	268±7.3	–4.017	0.0001
Invalid cue RT (ms)	332±11.8			311±8		
Post						
Valid cue RT (ms)	291±10.9	–4.197	0.0001	266±7.5	–4.015	0.0001
Invalid cue RT (ms)	329±12.6			302±8.3		
Validity effect (ms)						
Pre	38.8±4.4	–0.41	0.68	42.7±5.2	–1.08	0.28
Post	38.7±5.1			36.6±6		

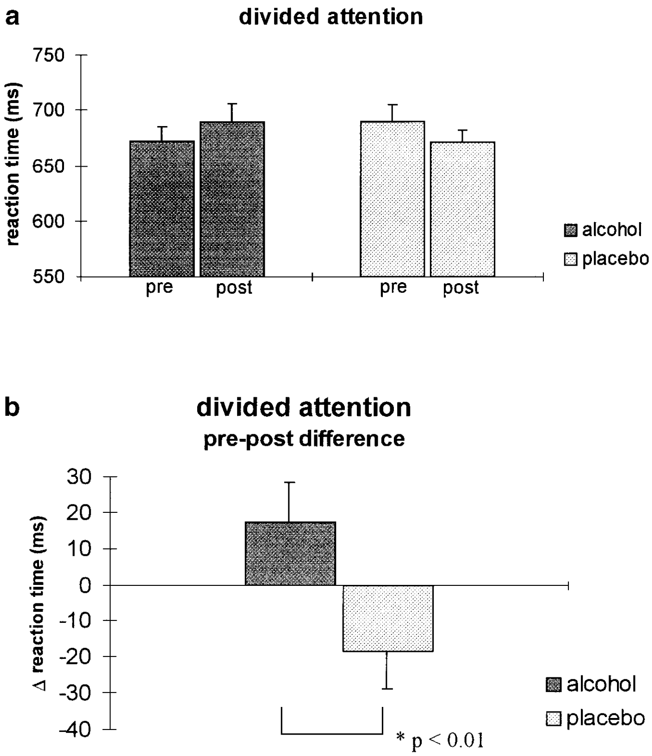

Fig. 2a, b Reaction time measurement in divided-attention task. **a** Group mean±SEM. **b** Difference between alcohol-group and placebo-group (pre-post difference)

Table 4 Influence of alcohol on the cue-validity effect in the visuo-spatial attention task (Posner paradigm). Lateralised validity effect (leftward cue valid/rightward cue valid)

Validity effect (ms)	Left	Right	*z*	*P*
Alcohol group (*n*=23)				
Pre	**34.5±5.1**	**43.2±5.1**	–1.67	0.094
Post	**21.3±6.4**	**56.1±7.4**	–3.29	0.001
z	–2.1	–1.57		
P	0.036	0.12		
Difference pre-post	**–13.2±6.6**	**13±8.6**	–2.01	0.045
Placebo group (*n*=23)				
Pre	**35.9±6.2**	**49.5±6.6**	–1.98	0.048
Post	**28.4±5.6**	**44.8±7.5**	–2.94	0.003
z	–1.26	–0.94		
P	0.21	0.35		
Difference pre-post	**–7.5±5.6**	**–4.7±6.4**	–0.37	0.72

in the error rate ($P<0.03$) and reaction times ($P<0.01$, Mann-Whitney *U*-test; Table 2). Reaction times decreased in the placebo group during the auditory task (by 35.6 ms), probably due to increased familiarity with the task (practice effect), so alcohol effects must be calculated as difference from the placebo values (see Fig. 2a, b). There is a relative increase in the alcohol group, of 40.5 ms in the visual task and of 29.8 ms in the auditory task. Note that the effects were not strong enough to reach significance when the two sensory tasks were considered alone ($P=0.21$, $P=0.06$, visual and auditory, respectively).

In the visuo-spatial attention task, reaction times are generally shorter in the valid-cue than in the invalid-cue condition. This finding was confirmed here for both the alcohol and placebo group and both for pre- and post-measurement ($P<0.0001$ in all four cases; Wilcoxon signed-rank test; Table 3).

To test the effect of alcohol on spatial orienting, the validity effect (difference of RT between valid-cue and invalid-cue cases) was computed for both groups. In neither group was there a significant pre-post change in the validity effect over all trials. However, when we reanalysed the data separately for the right versus left hemispace (or visual hemifield, respectively), we found a significantly reduced validity effect for the left visual field (right cerebral hemisphere) in the alcohol group ($P=0.036$), but not in the placebo group (Table 4).

Moreover, we observed such a left-right asymmetry of the validity effect already at pre-measurement ($P<0.05$ in the placebo group and a tendency, $P=0.094$ in the alcohol group), with the asymmetry substantially increased in the post-measurement, for both groups ($P<0.001$ and $P<0.003$ for the alcohol and the placebo group, respectively; Table 4). In all comparisons, the validity effect to the leftward targets (valid leftward cue minus invalid rightward cue) is smaller than the one for the rightward targets. Since we were mainly interested in whether this asymmetry would be influenced by alcohol, we computed the pre-post differences of the validity effects and compared those between left and right hemispace. We found further asymmetry in the alcohol ($P<0.05$), but not in the placebo group ($P=0.72$) (Table 4

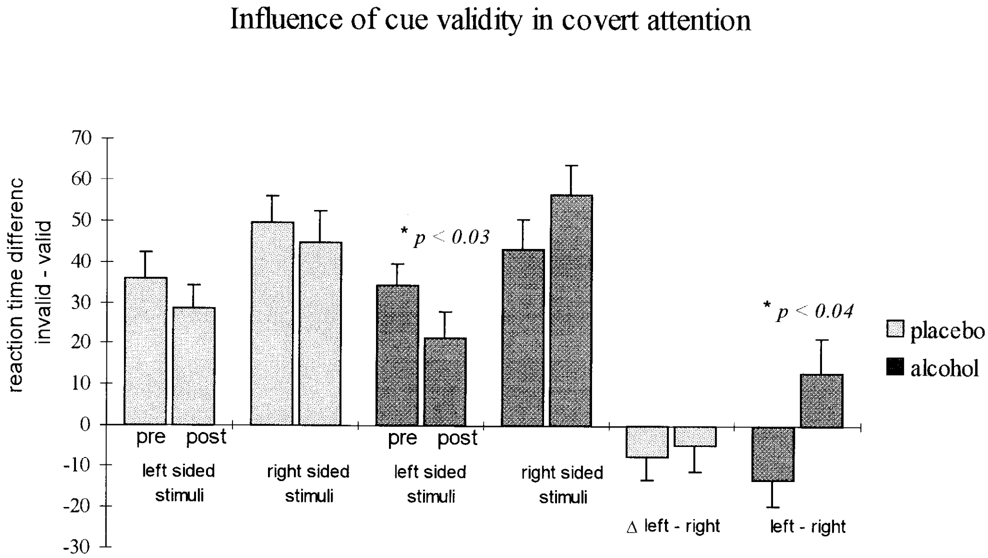

Fig. 3 Shift of covert attention: pre-post differences of the validity effects for the right versus left hemispace in both, the alcohol and the placebo group (mean±SEM)

and Fig. 3). To test for a possible effect of response bias we analysed the error rate. There was no significant difference in misses, anticipations and false positives in the pre- (placebo group: 4%; alcohol group: 3% error rate) compared to the post- measurement (both groups: 3% error rate), neither in the alcohol nor in the placebo group (both groups: Z=–1.66, P=0.1). From this we conclude, that the significant side specific pre-post difference of the validity effect is caused by the experimental condition alcohol (versus placebo) and does not result from response bias.

For better estimation of the effect of alcohol on spatial selective attention we conducted an omnibus ANOVA (independent variables: group (alcohol/placebo), time (pre/post), side (left/right); dependent variable: validity effect) and refined the model according to our hypothesis. The ANOVA revealed a significant effect of the model tested [$F(7,176)=3.07$, $P<0.004$] with a significant effect of the side variable (left/right) [$F(1,176)=16$, $P<0.0001$]. Because of the overwhelming effect of side, smaller effects could be covered. Thus, analogous to our procedure in the non-parametric analysis aiming to test for differences in the alcohol and in the placebo group, we conducted a two-way ANOVA (time, side) for each group separately. In the placebo group, we found a significant effect of side [$F(1,88)=5.29$, $P<0.03$], and in the alcohol group we also found a significant effect of side [$F(1,88)=11.22$, $P<0.01$] and, additionally, a significant interaction [$F(1,88)=4.01$, $P<0.048$]. Thus, the results from parametric statistics confirm the results from non-parametric tests.

Whereas under placebo conditions the validity effect is slightly reduced during the course of the experiment (by 7.5 and 4.7 ms), alcohol induces a more pronounced decrease of the validity effect for the leftward-valid cues but leads to an increased validity effect for rightward-valid cues. Thus, under the influence of moderate alcohol there is a *reduction* of false-cueing disturbance for left-appearing stimuli (by –13.2 ms) but an *increase* of disturbance for rightward stimuli (by 13 ms), i.e. a lateralised reaction pattern for spatial orienting.

For further investigation of an effect of side (left/right) of spatial orienting under alcohol consumption, one can compute pre-post differences of the validity effects, for the left and right visual field (VF): Conducting this analysis, i.e. a two-way ANOVA with *side* as within-subject and *group* as between-subject factor, we again found a significant effect of side [$F(1,44)=5.81$, $P<0.02$] and a close-to-significant interaction [$F(1,44)=3.77$, $P<0.058$].

Discussion

Our results show that moderate alcohol consumption has a significant effect on both divided attention and covert shift of spatial attention. With respect to divided attention, our findings confirm previous reports (e.g. Moskowitz and Robinson 1987) that divided-attention is impaired by acute, low levels of alcohol. We now showed that this is also true for moderate doses of alcohol: When results are corrected for improvement through repeated testing (practice effects), our data showed that subjects were less capable of dividing attention under the influence of moderate alcohol doses. In particular, error rates increased significantly in the alcohol condition.

In light of the global-slowing hypothesis (Maylor and Rabbitt 1993), it can be questioned whether effects of alcohol on human performance are specific to a process or more general, processing of all tasks being affected by reduced cognitive resources. The global-slowing hypothesis assumes that the longer a process takes without alcohol, the more it will be slowed by alcohol (Ryan et al. 1996). In our study, the overall longer RTs in the divided attention task indicate that it was more difficult than the selective spatial attention task, so that the global-slowing hypothesis would predict a higher slowing of RTs in the divided attention task. We did, in fact, find a clear alcohol effect in the divided attention task, but we also found a side-specific alcohol effect in the selective spatial attention task (with short RTs). Moreover, in detailed analyses of the divided-attention performance, alcohol significantly affected the auditory domain (with shorter RTs) whereas the changes in the visual domain (with longer RTs) did not reach significance. The two tasks imposed different demands on attention: The visual task was the more complex, and intake of alcohol led to prolonged reaction times whereas a shortening of RTs (after placebo) in the relatively easy auditory task was prevented by alcohol, thus RTs were only slightly reduced (see Table 2). We assume that the attentional interference depends upon task characteristics that require either preattentive or attentive mechanisms (Treisman and Gelade 1980). A break in the alternating tone sequence of the auditory task is easy to detect, "popping out" of the sequence of events might thus invoke preattentive mechanisms. In contrast, performing the visual task seems to require deliberate attentive mechanisms: During visual search, subjects have to detect four crosses forming the edges of a square, which do not "pop out" from the stimulus array. From this we argue that alcohol impairments in cognitive tasks after moderate alcohol consumption (0.6 g/kg body weight) originate from limitations on process-specific resources. Presumably, global slowing takes place after higher doses of alcohol consumption.

Activities like driving an automobile and simultaneously listening to surrounding noise and sounds may pose similar kinds of combined auditory-visual demands. Johnston (1982) assumed that secure driving requires the ability of dividing attention, e.g. of continuously tracking the curve path while assessing the degree of curvature to adjust driving speed. Maylor et al. (1990) found that the effects of both alcohol and practice on speed of detection were significantly greater under dual-task than under single-task conditions. Under alcohol, performance is impaired although the underlying mechanisms are not yet clear. From several studies it appears that the visual modality is not more affected by alcohol than the auditory domain, indicating that central factors are involved (see Koelega 1995, for review). Neuroimaging studies suggest that the dorsolateral prefrontal cortex and the anterior cingulate gyrus are involved in tasks of divided attention (Posner and DiGirolamo 1999).

With regard to results of previous studies, our findings concerning spatial attention are unexpected. Post et al. (1996) suggested that alcohol impairs performance in tasks that place demands on visual *spatial* attention, but we found no effect on the spatial shift of attention when we compared the pre and post measurement (see Table 3). We did find an effect, however, when we compared hemispheres, uncovering a lateralised influence of alcohol upon spatial attention (see Table 4). The *leftward decrease* and *rightward increase* of the validity effect can be interpreted as reduced leftward and improved rightward spatial orienting. The effect bears some similarity with the neglect syndrome, wherein patients fail to recognise the presence of objects presented in their contralesional hemispace (Marshall and Halligan 1994). Neglect predominantly occurs in the left hemispace (after damage of the right hemisphere), suggesting a major right-hemispheric influence on spatial attentional processes (DeRenzi 1982). In a PET study Corbetta et al. (1993) found lateralised parietal processing such that in the right superior parietal lobe, two distinct responses were localised, attending to the left and to the right visual field (VF) respectively, whereas in the left superior parietal lobe no difference in the activated cortical area was seen. Furthermore, attention to the left VF is mostly controlled by one region in the right parietal lobe while attention to the right VF is controlled more bilaterally, by a left parietal and a distinct right parietal region. These results correspond with the assumption of visuo-spatial attention of Mesulam (1985) and Heilman et al. (1985) who proposed that the right parietal lobe orients attention into both hemifields whereas the left parietal lobe directs attention only contralaterally, i.e. that the right VF is doubly presented and the left only singly. Thus, one should have a right-left difference of visuo-spatial attention, with a better ability of covert orienting in the right visual field (RVF) resulting in a greater RVF validity effect because of its bilateral representation. We indeed found a greater validity effect in the baseline conditions for targets in the right than for those in the left visual field, supporting the theory of Mesulam (1985).

Additionally, it is assumed that both hemispheres interact with each other in a dynamic push-pull fashion to equilibrate the direction of visuo-spatial attention (Kinsbourne 1977; Kinsbourne aand Bruce 1987; Reuter-Lorenz et al. 1990). In this activation-orienting model it is postulated that attention in space is biased in the direction contralateral to the more activated hemisphere. Differences of covert orienting between hemifields result from the interaction of the two hemispheres, i.e. a dynamic balance achieved by reciprocal inhibitory processes. In attentional orienting, rivalry may take place between the two hemispheres. In that model alcohol may lead to a reduction in the right-hemispheric predominance of activation in response to visual stimulation (Levin et al. 1998) or to an attenuation of the right-over-left asymmetry (Stenberg et al. 1994).

The model of Mesulam (1985), in accordance with the PET results of Corbetta et al. (1993) and our behavioural data, argue for a double bilateral presentation of the RVF and a single contralateral presentation of the LVF. As in the model of Kinsbourne (1977; Kinsbourne and Bruce 1987), both hemispheres encode the contralateral VF. In combination of the two models we conclude from our results, that alcohol might affect the interhemispheric balance resulting in a reduction of validity effects, i.e. the ability of covert orienting. Because the right hemisphere additionally encodes the ipsilesional VF, the validity effect in the RVF was enhanced in contrast to the validity effect in the LVF, which was reduced.

In the literature there is no clear explanation of how exactly the influence of alcohol affects visuo-spatial selective attention and why an effect could be lateralised. However, a number of findings may provide a working model through the mediation of GABA and its influence on the brain structures involved. In recent pharmacological studies, Witte and others investigated the effect of clonidine, an α_2 adrenoceptor agonist that stimulates endogenous GABA release, on cue-target detection tasks (CTD) in rhesus monkeys (Witte et al. 1992, 1997; Davidson et al. 1994; Witte and Marocco 1997). They found no effect on validity effects using low doses of clonidine but did find an effect on alerting scores. Clark et al. (1989), though, found somewhat differing results in humans. Clonidine affected the validity effect (valid RTs–invalid RTs) by decreasing response cost (invalid RTs–neutral RTs) with no change in response benefit (neutral RTs–valid RTs).

Clonidine stimulates the release of endogenous GABA in rat cerebral cortex and the release of GABA was found to be region specific. It was pronounced in the parietal and frontal cortex (Pittaluga and Raitieri 1988), i.e., main structures involved in attentional processing. Ethanol in turn seems to potentiate the action of endogenous GABA by increasing the sensitivity of the $GABA_A$ receptor subunit (in rats: Criswell et al. 1993; Soldo et al. 1994). Alcohol may thus act on the parietal cortex by increasing GABA-receptor sensitivity and on the behavioural side by decreasing spatial-attentional response costs.

The cognitive act of shifting attention from one position in the visual field to another has been conceptualised as composed of three mental operations (Posner and Petersen 1990), each being associated with a different brain region: disengagement of attention from its current focus (parietal cortex), moving attention to the target (superior colliculus), and (re-)engagement of attention at the target (lateral pulvinar of the thalamus) (see Ward and Brown 1996). Robinson and Petersen (1992) provide data on the influence of GABA on the pulvinar. When one side of the pulvinar is temporarily deactivated by injecting the GABA-agonist muscimol in the awake, behaving rhesus monkey, the animal can no longer properly engage attention in the contralateral field. Frontal cortex, parietal cortex and the pulvinar are the main parts of a complex network of spatial attention (La Berge 1983), in which a change in one structure will affect the whole network. Whereas the pulvinar is probably not lateralised (subserving the respective contralateral visual field), the parietal cortex certainly is (as can be seen from the predominance of left-field neglect) even though the precise role separation between left and right parietal cortex is still under debate. The difference that we found between visual fields in the cued target-detection task might thus underlie a right-parietal/pulvinar spatial-attentional priming process onto which alcohol exerts its effects through increased GABA sensitivity.

In future research, it will be interesting to further explore the influence of alcohol on lateralised attentional mechanisms. Egly et al. (1994) found in patients with left-hemispheric lesions that the deficit of disengagement occurred only for shifts between attended objects from the ipsilesional to the contralesional field and not during within-object shifts. This right-left hemisphere asymmetry in the shift of attention between and within objects was confirmed in a commissurotomised patient with disconnected neocortices (Egly et al. 1994). One could test whether alcohol consumption affects shifting of attention between visual-field locations only, assumed to be predominantly a right-hemispheric function, or whether it also affects the shifting of attention between objects rather than locations, assumedly a left hemispheric function. Coull and Nobre (1998) found that visuo-spatial selective attention is lateralised with a dominance of the right hemisphere whereas tasks concerning temporal selective attention are found to be associated with left hemispheric processing. Another concept is that of the local/global dichotomy. Robertson et al. (1988) for example found, in patients with left- versus right-sided parietal lesions, an asymmetry in their ability to focus attention on global versus local pattern characteristics (Navon patterns), with the right-parietal lesioned patients missing the global aspects and left-parietal lesioned missing the local aspects. Yamguchi et al. (2000) confirmed the above results providing an asymmetrical basis for the allocation of attention to global and local features in a study using event-related potentials (ERPs).

In summary, we have demonstrated that, following ingestion of a moderate amount of alcohol in tasks of divided and covert attention, performance is impaired. Our data indicate that the way alcohol influences attentional performance depends upon task characteristics. To our surprise, alcohol did not simply decrease attentional performance in a task of covert attention but had a lateralised effect, presumably having a neuronal base in the different roles of right versus left parietal lobes processing visuo-spatial information. Thus, alcohol seems to have a predominant and specific influence on attentional priming in the right hemisphere of the brain.

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