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Divided attention performance in cannabis users and non-users following alcohol and cannabis separately and in combination

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Abstract. The effect of Δ 9-tetrahydrocannabinol (Δ 9-THC) and alcohol, singly and in combination, on divided attention performance was investigated in cannabis users and non-users who were matched for alcohol use. Both cannabis and alcohol produced decrements in central and peripheral signal detections. Drug and alcohol effects were greater for signal presentations in the periphery. Cannabis users were less impaired in peripheral signal detection than non-users while intoxicated by cannabis and/or alcohol. These findings suggest the development of tolerance and cross-tolerance in regular cannabis users and/or the ability to compensate for intoxication effects.

Key words: Cannabis – Alcohol – Divided attention performance

Numerous studies have catalogued the evidence that alcohol effects driving-related performance both singly and in combination with other drugs such as cannabis (e.g., Milner 1972; Binder 1973; Rafaelson et al. 1973; Moskowitz and Sharma 1974; Brewer and Sandow 1980; Moskowitz et al. 1985). Recent interest in the idea of risk compensation and homeostasis has focussed on the question of increased risk-taking as a function of improved safety measures (McKenna 1985; Oppe 1988). The theory of risk homeostasis also suggests the possibility that subjects can attempt to make their performance less risky in an effort to compensate for the perceived decrements caused by intoxication. Some evidence suggests that the effects on risk taking are different for alcohol and cannabis (Smiley 1986). In addition to any risk compensation there is the possibility of tolerance effects at a physiological level.

In a previous study it was observed that divided attention performance while intoxicated is facilitated by previous drug experience (MacAvoy and Marks 1975). Unfortunately, subjects forming the cannabis user group were found to have a significantly higher rate of alcohol consumption that the non-users and simultaneous use of alcohol and cannabis was reportedly a regular feature of their drug taking habits. In view of this confounding of variables it was important to run a further experiment in which experienced cannabis users are matched on their alcohol consumption rates with subjects forming the cannabis naive group.

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The previous study reported by MacAvoy and Marks (1975) found that divided attention performance was impaired by cannabis but, surprisingly, not by alcohol. It was suggested that the lack of sensitivity to the effects of alcohol in this experiment could have resulted from: (a) the ease with which subjects could detect central signals and (b) the fact that alcohol was a between subjects factor. In the experiment reported here the central task was made more demanding by shortening the signal duration from 2.5 s to 1.5 s. At the same time the number of signal sources was increased and the task duration was lengthened to 40 min. In addition both alcohol and cannabis were made within-subject factors. It was hypothesized that divided attention performance would be impaired by both substances but that experienced users of cannabis would be less impaired than non-users while intoxicated.

Methods

Subjects. Twelve volunteers, all attending tertiary educational institutions, served as subjects in two equal groups. One contained six experienced cannabis users and the other six subjects naive to cannabis. Each group contained three males and three females. Cannabis users had a mean consumption rate of three joints per week (range 1.5–6) and had been exposed to this pattern of use for an average of 5.5 ± 1.5 years. All subjects were regular users of alcohol with a mean consumption of 13 drink units per week. The subjects' mean age was 23.4 ± 2.62 years and their mean body weight was 77.48 ± 9.5 kg for males and 54.2 ± 14.0 kg for females.

Apparatus. The apparatus and the physical setting in this experiment was identical to that used by MacAvoy and Marks (1975). The subject faced a central light surrounded by ten peripheral lights spaced at 15° intervals along a horizontal perimeter. Two types of signals were presented; (a) a brief interruption in the regular flashing of the central light, and (b) a brief flash of one of ten peripheral lights. The flash duration for both signal sources was 0.5 s, with an interstimulus flash interval of 1.0 s for the centre light, which was programmed to produce random breaks in the flashes at an average of one break every 20 s. All signal lights were coloured red.

The data-recording programme was run over eight 5-min blocks, each containing 30 signals in random order but with an equal probability of either central or peripheral signals occurring.

The centre light break in regular flashes (i.e., the centre light signal) was set at 1.5 s. The central signal was therefore achieved by delaying a centre light flash for an extra 0.5 s after the previous light flash, instead of 1 s as was the case for all non-signals. The clocks recording response times were initiated at a time 1.1 s after the previous flash and remained open for 1.4 s.

Response times (for central signal detections only) were recorded within 0.1 s time intervals. If no response was made to a signal within the 1.4 s "hit" period a missed signal was recorded. Subjects were provided with immediate feedback on the accuracy of their performance. Directly above the centre light were two larger lights, one red and the other green. A flash of the green light indicated to the subject that a signal had occurred (either central or peripheral), and that a "hit" had been scored. The red light flashed only when a signal had occurred and no response had been made to it. This feedback system enabled the subject to assess his/her performance and provided reinforcement.

Preparation of drugs. Chemical assay of the cannabis material determined that the plant material contained 1.31% Δ 9-THC. All cigarettes were made up to a standard weight of 770 mg using a hand-operated rolling machine. The allowance of an extra 70 mg of material in each cigarette was designed to ensure delivery of the required dose. A mark was placed at a point 8 mm from the end of the cigarette and the cigarette was smoked up to this mark. The cigarette contained mixtures of detoxified plant material and material containing 1.32% Δ 9-THC, such that the three presented doses were 0, 2.6 and 5.2 mg Δ 9-THC.

The target alcohol intoxication levels of 50 and 100 mg% were induced by giving subjects 1.19 ml/kg and 2.38 ml/kg vodka (Wolfschmidt) containing 42% w/v ethanol. The active and placebo drink were prepared by mixing with 10 ml concentrated lime extract and Coca Cola to make a 400 ml drink served in two glasses. Estimates of blood alcohol concentration were obtained using a standard model 900 Stephenson Breathalyzer, and regulation ampoules.

Procedure. Three levels of cannabis were combined with three levels of alcohol to give a total of nine treatment combinations which were administered in random order to all subjects in a repeated measure design. Before testing sessions began each subject was familiarized with the laboratory and its equipment. Subjects practised on the divided attention apparatus until an errorless performance over a 5 min period was obtained.

On each of the 9 days of testing subjects were weighed and a check was made to ensure the pre-test requirements had been observed. These were that (a) no drugs, prescribed or otherwise had been consumed over the previous 24 h; (b) no tea, coffee or food had been consumed within 4 h of attending the laboratory. The assigned dose of alcohol was administered and consumed within 15 min. For the absorption phase the subject was seated in a comfortable chair and engaged in light conversation, or allowed to read the magazines provided. The cigarette was then presented to the subject in a small holder and subjects were instructed to adopt a standard paced method of smoking. This involved deep inhalation of smoke into the lungs and the retention of that smoke for a period of 20 s. Fifteen seconds was allowed between puffs. The technique of blowing against a closed mouth and nose aided the naive subjects when the smoke induced coughing. A maximum of 10 min was allowed for the cigarette to be smoked and all subjects had little difficulty in completing this phase in the time allowed. Breath analyses were obtained twice during the session, 35 min after the drink was consumed and at the end of the session, 115 min after consumption. The time sequence for each experimental session is given in Table 1. Following the first breathalyzer test the subject was seated in front of the apparatus and read the instructions. After answering any queries ear muffs were placed in position and the task was started.

Table 1. Protocol for cannabis-alcohol investigation

Time since entering laboratory	Event
0.00–0.15	Active or placebo drink presented and consumed
0.15–0.35	Absorption phase
0.35–0.45	Active or placebo cigarette presented and consumed
0.45–0.50	Breathalyzer test
0.50–1.30	Divided attention task
1.30–1.35	Peripheral vision tested*
1.35–2.00	Motor task*
2.00–2.05	Final breathalyzer test
2.05–2.15	Subjective questionnaire*

* These data are to be reported elsewhere

Results

Blood alcohol concentrations

Blood alcohol readings were taken 35 min after the alcohol was consumed and again 105 min later. The first breath analyses resulted in a mean blood alcohol concentration of 48 ± 4 mg% and 97 ± 9 mg% following the administration of 1.19 mg/kg and 2.38 mg/kg, respectively. Considering the tendency for the "Breathalyzer" to slightly underestimate the blood alcohol concentration, it is likely that the subjects were close to the intended BACs of 50 and 100 mg% by the time the divided attention task began. Readings taken at the end of the experimental session, 1 h and 45 min after the alcohol had been consumed, indicated that the mean BAC for the low dose treatment had dropped to 38.7 ± 7 mg% while the high dose treatment had dropped to a mean BAC of 89 ± 5 mg%. Since the expected elimination rate is approximately 10 mg/h (Dubowski 1961) the latter readings fall within the expected range. No differences in the rate of elimination were demonstrated between the sexes or user/non-user groups.

Divided attention task

Central signal performance. A four-way analysis of variance with repeated measures on both Alcohol and Cannabis was performed on all measures, except in the case of central response times, when a five-way analysis was performed. The four factors were Experience-with-cannabis, Sex, Alcohol and Cannabis. Because of the large number of effects and interactions to be tested, a P level of 0.025 was adopted. A highly significant deterioration in subjects' ability to detect central signals resulted from cannabis administration

($F=8.29$; $df=2.16$; $P<0.0005$). Duncan's test indicated that only the high dose treatment differed significantly from the placebo. Alcohol also resulted in an increase in central misses with the high BAC (97 mg%) producing approximately twice the number of misses when compared to the other two treatment levels. However the main effect of alcohol just failed to reach the 0.025 level of significance ($F=4.64$; $df=2,16$; $P<0.05$). No interactions occurred between any of the four factors.

A significant increase in the number of false detections occurred following alcohol ($F=14.2$; $df=2,16$; $P<0.001$) but not following the administration of cannabis. Duncan's Test indicated that a significant increase in false detections resulted only when the high dose of alcohol had been received.

Alcohol and Experience-with-cannabis interacted with Sex to produce a significant interaction ($F=11.84$; $df=2,16$; $P<0.001$). This interaction revealed that male users and female non-users scored a high number of false detections, particularly when intoxicated at a BAC of 97 mg%. Both the non-user males and the user females scored relatively few false detections under any of the treatment conditions.

A signal detection analysis indicated that both cannabis and alcohol had a highly significant effect in reducing subjects' sensitivity to the central signal ($F=11.85$; $df=2,16$; $P<0.001$, and $F=14.33$; $df=2,16$; $P<0.001$, respectively). Duncan's test revealed that only the high cannabis dose resulted in a significant reduction from that of the placebo treatment. Similarly Duncan's Test indicated that only the high BAC treatment led to a significant reduction. No significant interactions occurred on any of the four factors. Although not significant, cannabis users tended to be less affected by the two drugs than did the non-users. Beta was unaffected by either drug and no interactions occurred.

A five-way analysis of variance was performed on the mean response times for each block. Time on the task had a significant effect on response times to the central signal ($F=20.5$; $df=7.56$; $P<0.001$). Response times were shortest in the first 5-min block, increased in the next 5-min block, and then remained relatively constant throughout the remainder of the task. Duncan's Test indicated that response times in the first 5 min differed significantly from all remaining time blocks except the second. The remaining seven blocks did not differ significantly from one another.

Alcohol had a significant effect in lengthening response times to the central signal. Duncan's Test indicated that only the high BAC increased response times significantly from the other two treatments ($F=5.436$; $df=2,16$; $P<0.025$). Cannabis had no significant main effect on central response times. A significant three-way interaction occurred between the factors of Alcohol, Cannabis and Time-on-task ($F=1.593$; $df=28,224$; $P<0.025$) which revealed that when cannabis was administered in the absence of alcohol response times increased over each 5-min time block as compared to the condition in which neither drug was received. The magnitude of such increases were very small and their sum at the end of 40 min only exceeded the double placebo condition by 0.04 s. The addition of alcohol at either dose level further increased response times, although again this was of small magnitude (0.01 s) and the response times resulting from the two drugs in combination did not differ significantly from the response times produced by alcohol alone. A complex four-way interaction between the factors of Experience-with-cannabis, Sex, Cannabis, and Time-on-task also occurred ($F=5.5418$; $df=14,112$; $P<0.001$).

Peripheral signal performance. Four-way analyses of variance were performed on all measures with the exception of the analysis of misses which was analysed using a five-way analysis, angle of presentation being the extra factor. Both alcohol and cannabis significantly increased the number of missed peripheral signals ($F=17.22$; $df=2,16$; $P<0.001$ and $F=9.52$; $df=2,16$; $P<0.005$, respectively). Only the high alcohol dose consistently increased the number of missed signals and this was confirmed by Duncan's Test, which indicated that the mean number of missed signals following the high alcohol dose differed significantly from the other two treatments whose means did not differ significantly. The significant cannabis effect revealed a dose-related trend for missed peripheral signals, although Duncan's Test indicated that only the high dose of cannabis led to a significant increase in misses over the placebo treatment.

A five-way ANOVA was performed of the number of signals missed as a function of the angle of presentation. As the number of misses on the left and right sides were approximately equal, the data for the two sides were combined for this analysis. Angle of presentation had a highly significant effect on the mean number of peripheral signals undetected: the more extreme the angle the greater the probability that the subject would miss ($F=47.91$; $df=4,32$; $P<0.001$). Duncan's Test revealed that the mean number of missed signals at 75° was significantly higher than at any other angle. Of the remaining signal angles, 60° and 45° differed significantly from 15° but did not differ from each other or from the 30° signal source.

Three significant two-way interactions occurred between the factors of Experience-with-cannabis and Angle-of-presentation ($F=7.13$; $df=4,32$; $P<0.001$), Alcohol and Angle-of-presentation ($F=3.42$; $df=8.64$; $P<0.005$) and Cannabis and Angle-of-presentation ($F=3.03$; $df=8,64$; $P<0.005$). As indicated in Fig. 1, the user group missed fewer of the more peripherally located signals under all conditions, particularly when intoxicated with the high BAC. Figure 2 represents the interaction of angle with the factors of Experience and Cannabis. Non-users demonstrated an approximate linear relationship between the increased frequency of missed signals with the increased angle of presentation. This relationship appears to be dose related to the cannabis treatment levels. Users, on the other hand, demonstrated a similar performance to that found under alcohol, with a less severe deterioration in performance occurring peripherally.

Figures 1 and 2 represent the effects of alcohol or cannabis summed across cannabis or alcohol conditions, respectively. Analysis of the effects of angle on miss rates when each drug was administered alone produced curves for both alcohol and cannabis which closely followed those in Figs. 1 and 2. The number of undetected signals at the most extreme angle of presentation (75°) was significantly higher in users than non-users when the high dose of alcohol was administered ($t=2.46$; $df=6$; $P<0.05$), but the differences at the remaining angles were not significantly different. A similar analysis for the high dose of cannabis just failed to reach significance. A four-way interaction between Experience-with-cannabis, Sex, Cannabis and Angle also proved to be significant ($F=3.48$; $df=8,64$; $P<0.002$).

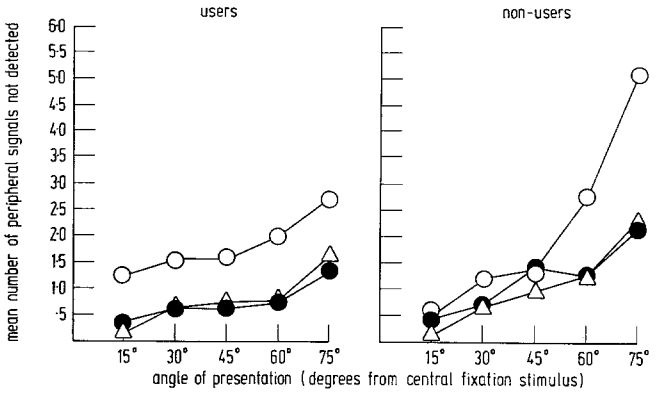

Fig. 1. The number of missed peripheral signals as a function of Angle of presentation, Experience-with-cannabis and Alcohol treatment levels. ● Placebo drink; △ B.A.C. 48 mg%; ○ B.A.C. 97 mg%

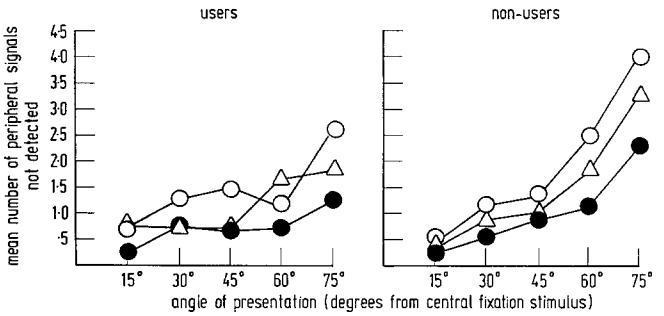

Fig. 2. The number of missed peripheral signals as a function of Angle of presentation, Experience-with-cannabis and Cannabis treatment levels. ● Placebo cig; △ 2.62 mg THC; ○ 5.24 mg THC

A significant increase in the number of false alarms of peripheral signals resulted only when alcohol was administered ($F=13.37$; $df=2,16$; $P<0.001$). Duncan's Test indicated that only the high BAC resulted in a significant increase in false alarms. There were no interactions between any of the four factors.

Signal detection analysis revealed that both drugs significantly reduced sensitivity to peripheral signals. The significant alcohol effect ($F=14.33$; $df=2,16$; $P<0.001$) was produced by the high BAC which led to a marked reduction in subjects' sensitivity. Cannabis led to a dose-related reduction in sensitivity ($F=11.846$; $df=2,16$; $P<0.001$). Duncan's Test revealed that the low and the high dose treatment means differed significantly from one another as both did from the placebo. There were no significant interactions between any of the four factors and the criterion (β) was unaffected by any factor or interaction on this aspect of the task.

Discussion

This experiment differed from the experiment previously reported by MacAvoy and Marks (1975) in three important ways. Firstly, both alcohol and cannabis were within-subjects factors; secondly, the central task demands were greater; and finally, cannabis users were matched with non-users with respect to alcohol consumption. In this experiment, both cannabis and alcohol were found to have significant effects on all aspects of the divided attention task. The higher dose of alcohol impaired subjects' sensitivity to both signals and induced longer response times to the central signal while for cannabis the effects were dose dependent.

The number of signals missed from each signal source did not differ greatly. This finding is in contrast to a study by Moskowitz and Sharma (1974), who reported that peripheral detections decreased as a function of central task complexity but that central task detections showed only minor impairment when subjects were intoxicated with alcohol. The discrepancy in results may be a function of signal distribution. In this experiment the probability of a signal occurring in central and peripheral positions was 0.50. The frequencies of signals appearing at each angle of presentation were also equal. Hockey (1970) reported that on a divided attention task the visual area least affected is the one upon which the greatest demands have been placed. This conclusion is therefore supported by the data from this experiment.

Only one interaction occurred which involved both alcohol and cannabis, together with time-on-task, in central response times. The magnitude of the interaction was small, however, and overall the two drugs showed no interactive effects.

The user and non-user groups differed in their ability to detect peripheral signals in the divided attention task. The user group missed fewer signals at more extreme angles of presentation than did the non-user group (see Figs. 1 and 2). Users were certainly not immune to drug and alcohol effects, however, and small increases in missed peripheral signals occurred following either drug. This finding suggests that users divided their attention between signal sources more efficiently and were able to process information more effectively from the whole of the display than non-users, who showed a marked deterioration in performance as a function of the angle of presentation. The effect was prominent when intoxicated at the high BAC level and showed a dose-related response for the cannabis treatment levels. Either drug alone produced almost identical curves to those illustrated in Figs. 1 and 2, which represent the effects of one drug summed across all levels of the other. These results demonstrate that cannabis users develop tolerance to cannabis and cross-tolerance to moderate quantities of alcohol and/or that users can learn to compensate for drug and alcohol effects.

The fact that user and non-users subjects were matched on their alcohol consumption patterns means that *alcohol* tolerance can be eliminated as an interpretation of the findings, something that could not be ruled out in the previous study (MacAvoy and Marks 1975). There is other evidence in the literature of cross-tolerance between cannabis and depressants, such as alcohol, in humans. Pyrahexal has been found to relieve post-alcohol symptoms (Thompson and Proctor 1953), while Jones and Stone (1970) noted a resistance in heavy cannabis users to large doses of alcohol. However tolerance and cross-tolerance are only one possible explanation of the observed interaction between experience and signal angle on detection rates.

An alternative explanation of these findings is that *users* learn to *compensate* for the effects of cannabis and alcohol. Such an interpretation would imply that cannabis users are capable of gaining volitional control over the drug effects which they may well have been motivated to try to do. This interpretation of the present findings receives support from the conclusion reached elsewhere that cannabis effects contain a large placebo component (Jones and Stone 1970; Marks and Von Dadelszen, submitteed for publication). While it is not possible to delineate whether physiological tolerance or learned compensation explains the present data, in either case the results indicate a lesser performance decrement among regular users of the drug following both alcohol and cannabis consumption.

To summarize, the present findings on divided attention indicate the following conclusions:

The central task

(a) Signal detection is significantly impaired by cannabis, but only at the high dose administered. Alcohol, while not significant as a main effect on centre signal detections, induces an increase in false alarms.
(b) Sensitivity (d') is significantly reduced in all subjects following either cannabis or alcohol, although only at higher dose levels. β is unaffected by either drug.
(c) Response times are lengthened by alcohol, particularly at the BAC of 97 mg%, but cannabis does not influence this measure.

The peripheral task

(a) Miss rates in the peripheral visual display are significantly increased following high doses of both drugs.
(b) For all subjects, the probability of misses increases as a function of angle of presentation. The high dose of alcohol resulted in a significant increase in the probability of a miss at the more extreme angle of presentation. Cannabis has a similar, but dose-related result.
(c) The false alarm rate increases under the high dose of alcohol but not cannabis.
(d) Sensitivity to peripheral signals is significantly reduced at both dose levels of each drug, but β is unaffected.
(e) Non-users are more impaired than users under intoxication of both drugs in their ability to detect signals in the periphery. Either users develop tolerance to cannabis and cross-tolerance to alcohol or are able to compensate for the effects of drug and alcohol intoxication. Further studies are required to differentiate between the tolerance and compensation interpretations of the findings.

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