Low doses of marijuana and alcohol severely impair driving when taken together

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Abstract
The purpose of the present studies was to empirically determine the separate and combined effects of Δ^9–tetrahydrocannabinol (THC) and alcohol on actual driving performance. In the first study, eighteen recreational THC users were treated with drugs and placebo according to a balanced, 6-way, observer and subject blind, cross-over design. On separate evenings they were given THC placebo, THC 100 µg/kg and THC 200 µg/kg with and without alcohol. Alcohol doses were sufficient to sustain blood alcohol concentrations (BACs) of around 0.4 g/dl during testing. Subjects conducted two driving tests at each occasion: i.e. the Road Tracking Test and a Car-Following Test. In the second study 16 recreational users were treated with drugs and placebo according to a balanced, 4-way, cross-over, observer and subject-blind design. On separate evening they were treated with THC placebo and THC 100 µg/kg with and without alcohol. As in the first study, alcohol doses were sufficient to sustain BACs of around 0.4 g/dl during testing. Subjects conducted a City Driving Test. Both THC doses alone, and alcohol alone, significantly impaired the subjects' Road Tracking and Car-Following performances. Both THC doses in combination with alcohol severely impaired the subjects' performance in each test. In the City Driving Test, the combination of THC 100 µg/kg and alcohol significantly reduced the frequency of visual search for traffic at intersections. While the effects of THC alone in doses up to 200 µg/kg might be categorized as "moderate", they become "severe" when THC is combined with a low dose of alcohol.

Introduction

There is no doubt that THC impairs its users cognitive and psychomotor abilities to an extend largely determined by the inhaled or ingested dose. It is also certain that the dose preferred by cannabis smokers (around 300 µg/kg) is sufficient for impairing performance in potentially dangerous tasks such as driving. It is less certain that those doses cause the degrees of impairment that seriously compromise driving ability. Epidemiological surveys conducted in the widely separated localities have generally revealed that the presence of THC in between 4 and 12% of drivers who sustained injuries or death in crashes (review: Robbe, 1994). Although the prevalence of THC users in the general driving population is generally assumed to be lower, these data cannot

be accepted as evidence showing that THC was responsible for the crashes. The reason is that alcohol, usually in concentrations associated with a high crash risk, was also found in 50-90% of the same drivers. The 1996 National Household Survey of Drug Abuse (Townsend et al, 1998) indicated that the concurrent use of alcohol is common among THC smokers in general. Whereas 4 percent of the respondents admitted to driving following the use of THC, about 80% of the latter also reported the combined use of a moderate dose of alcohol. THC thus may offer the most hazardous potential when combined with alcohol, especially at low blood alcohol concentrations (BAC). However, we know little about the exact nature and extend of any additional impairment to which THC increases driving impairment at low BAC levels.

Numerous experimental studies have already been undertaken for that purpose (reviews Robbe, 1994, Chester, 1995). Most are of limited relevance in the present context since the laboratory psychomotor tests they employed were short and relatively simple, bearing almost no resemblance to actual driving. In general, these studies have shown little or no effects of THC alone in doses up to 250 .g/kg, little or no effect of alcohol in BACs of 0.10 g/dl and nothing more than an additive effect of the two drugs in combination. That is, their combined effects were essentially no greater than the sum of changes that each drug produced separately. Chester noted, however, that the drugs' impairing effects in some laboratory tasks have differed qualitatively. Thus the combination might simultaneously degrade different mental functions that independently affect performance in complex real-life tasks. That being the case, one might even expect the simultaneous effects of THC and alcohol to seriously degrade complex performance, even if those effects are not synergistic in the classic pharmacological sense.

The present research represents another attempt to empirically determine the separate and combined effects of THC and alcohol on driving. It differs from its predecessors by employing standardized tests for objectively measuring the drugs' effects on driving performance in the natural environment; i.e. on real roads in normal traffic. The research program consisted of two driving studies in which a variety of driving tasks was monitored. These included maintenance of a constant speed and steady lateral position during uninterrupted highway travel, reaction time to deceleration maneuvers of leading vehicle while driving in tandem on a highway, and general driving proficiency and visual search during city driving. It was expected that these studies would provide better insight into the combined effect of THC and alcohol, and demonstrate whether the drugs' combined effects are additive or synergistic.

General procedures

Subjects in both studies were recreational users of marijuana, i.e. they smoked THC more than once a month, but not daily. They were used to consume alcohol at least once a week. They were all healthy, between 21 and 40 years of age, had normal weight and binocular acuity, and were licensed to drive an automobile. They were informed about the nature of the study and gave informed consent prior to their participation. Furthermore, law enforcement authorities were contacted to verify that they had no previous arrests or convictions for drunken driving or drug trafficking.

Each subject was required to submit a urine sample immediately upon arrival at the test site. Samples were assayed qualitatively for the following drugs: cannabinoids, benzodiazepines, opiates, cocaine, amphetamines and barbiturates. In addition, a breath sample was analyzed for the presence of alcohol.

Marijuana and placebo cigarettes were supplied by the US National Institute on Drug Abuse (NIDA). The lowest and the highest THC concentrations in the marijuana cigarettes used in the present studies were 2.2 and 3.95%, respectively. Cigarettes were cut to provide lengths appropriate for the subjects' weight. Placebo cigarettes were similarly shortened. All were humidified before the subjects smoked them as completely as possible through a plastic holder in their customary fashion.

Subjects were accompanied during every driving test by a licensed driving instructor. A redundant control system in the test vehicle was available for controlling the car, should emergency situations arise.

Study 1: Highway driving under the influence of marijuana and alcohol

Methods

Eighteen volunteers, equally comprised of men and women, participated in the present study. They were treated with drugs and placebo according to a balanced, 6-way, observer- and subject blind, cross-over design. On separate evenings they were given weight calibrated doses of THC and alcohol, or placebos for one or both substances as follows: alcohol placebo + THC placebo, alcohol placebo + THC 100 .g/kg, alcohol placebo + THC 200 .g/kg, alcohol + THC placebo, alcohol + THC 100 .g/kg, alcohol + THC 200 .g/kg. The initial alcohol dose was sufficient for achieving a peak BAC of about 0.07 g/dl. Booster doses were later given to sustain BAC around 0.04 g/dl during testing.

Initial drinking preceded smoking by 60 minutes. Driving tests began 30 min after smoking at 21:00 h. Subjects undertook the tests in pairs the same evening. One started with the car-following test and the other 4 min later with the road tracking test. After a driving distance of 40 km on the highway, the first subject drove off and awaited the second. When he/she arrived, the pair exchanged roles, returned to the highway, and drove in the reverse direction until returning to the origin where bot paused for 15 min. A second booster dose of alcohol was then administered to subjects with BACs below 0.05 g/dl. Beginning around 22:15 h, the subjects drove through another circuit while repeating the same series of tests as before. Testing concluded at approximately 23:15 h.

Road Tracking and Car-Following Test

In the Road Tracking Test, the subject attempted to maintain a constant speed of 100 km/h and a steady lateral position between the delineated boundaries of the right (slower) traffic lane. Standard deviation of lateral position (SDLP) was the primary outcome variable. SDLP is a measure of road tracking error, in practical terms, a composite index of allowed weaving, swerving and overcorrecting. Failures to restrict the vehicle's lateral motion within lane boundaries were recorded together as the percentage of time out of lane (TOL). The Car-Following Test involved the use of two vehicles. The preceding vehicle was under an investigator's control, and the following vehicle, the subject's. The test began with the two vehicles travelling in tandem at speeds of 100 km/h. Subjects attempted to drive 50 m behind the preceding vehicle and to maintain that headway as it executed a series of alternating acceleration and deceleration manoeuvres lasting 33 sec apiece. The investigator driving the preceding vehicle initiated each manoeuvre by activating a microprocessor driven cruise control. The vehicle's speed then rose or fell in a constant manner until arriving at a point 15 km/h higher or lower then were it began. About eight manoeuvres in each direction were accomplished over both repetitions of the tests. Headway was continuously recorded, as were the subject's discrete reaction times (RT) at the beginning of manoeuvres. Average RT and the standard deviation of headway (SDH) for acceleration and deceleration manoeuvres were the dependent variables.

Results

Both THC doses alone, and alcohol alone, significantly impaired the subjects' Road Tracking and Car Following performances. In practical terms, the magnitude of the mean effects were minor after alcohol and moderate after THC 100 and 200 .g/kg. Both THC doses in combination with alcohol severely impaired the subjects' performance in both tests. Univariate analysis of variance showed that all drug combination significantly increased SDLP relative to double placebo (Figure 1). Mean TOL rose exponentially with SDLP. Beginning at the placebo level of 0.2%, mean TOL increased with the severity of drug effects until reaching 1.1% after the combination of alcohol and THC 200 .g/kg. Mean RT and SDH during deceleration maneuvers varied across treatment conditions in the same manner. Beginning at the placebo level of 4.65 sec, mean RT lengthened to 6.33 (+36%) under the combined influence of alcohol and THC 200 .g/kg (Figure 2). Only in the latter condition,

the change in RT, reached statistical significance. The change in mean SDH was from 5.69 to 7.78 m (+37%). This time all changes from double placebo were significant.

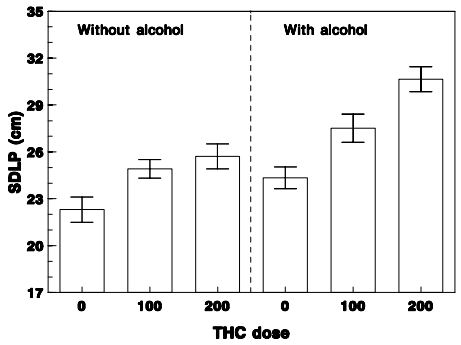

Figure 1. Mean (ñSE) SDLP in the Road Tracking Test by THC dose and absence or presence of alcohol (averaged across repetitions)

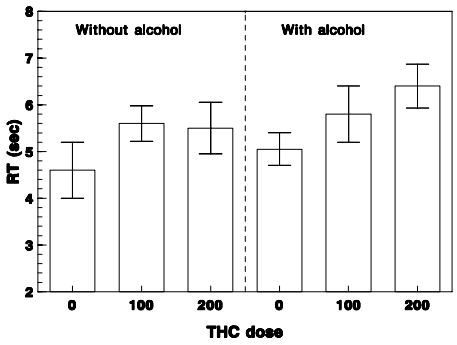

Figure 2. Mean (ñSE) RT to decelerations in the Car–Following Test by THC dose and absence or presence of alcohol (averaged across repetitions)

Study 2: Urban city driving under the influence of marijuana and alcohol.

Method

Sixteen recreational users, equally comprised of men and women, were treated with drugs and placebo according to a balanced, 4-way, observer- and subjects blind, cross-over design. On separate evenings they were given weight calibrated doses of THC and alcohol, or placebos for one or both substances as follows: alcohol placebo + THC placebo, alcohol placebo + THC 100 .g/kg, alcohol + THC placebo, alcohol + THC 100 .g/kg. The initial alcohol dose was sufficient for achieving a BAC of about 0.04 g/dl at the beginning of the driving test. Those failing to reach the expected peak were given a booster dose to achieve BAC around 0.04 g/dl during testing.

Initial drinking preceded smoking by 45 minutes. Driving tests began 25 min after smoking and lasted 45 min. The city driving tests were conducted between 20:30 and 22:30 h. Successive test sessions were ordinarily scheduled for particular subjects at weekly intervals.

City Driving Test

The City Driving Tests were conducted in the evening over a constant route (∀15 km) within the city of Maastricht. The route was constructed through business and residential areas on 2-lane undivided streets and included a 5 km, 4-lane divided segment on a major cross-city thoroughfare. Manoeuvres included left and right turns at some intersections and driving trough others, left and right lane changes, responding to traffic control devices, and a turn on residential street. A shortened version of the Royal Dutch Tourist Association Driving Proficiency Test was used by the licensed driving instructor for rating the drivers' performance in retrospect. In total 90 items were scored dichotomously as either pass or fail. Total test performance was scored by the percentage of items scored as "pass". Subscores were calculated for vehicle checks, vehicle handling, traffic manoeuvres, observation and understanding traffic and turning. In addition, an eye movement recording system was mounted on the subjects' head for providing relative frequency measures of appropriate visual search at intersections. The number of times a subject checked for traffic at intersections was taken as the dependent variable.

Results

After placebo treatment subjects looked at side streets from the right in 84% of all cases. Visual search frequency of these subjects did not change when treated with alcohol or THC 100 .g/kg alone. However when treated with the combination of alcohol and THC the frequency of visual search significantly dropped by 3%. Mean (∀SE) frequency of visual search for traffic at

intersections in each treatment condition is shown in Figure 3. Performance as rated on the Driving Proficiency Scale did not differ between treatments.

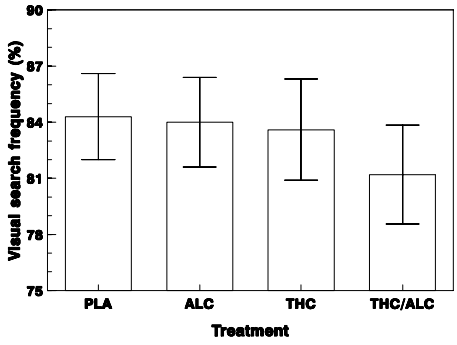

Figure 3. Mean (±SE) frequency of visual search for traffic at intersections in the City Driving Test by each treatment condition

Discussion

The subjects' performance in the road tracking test clearly showed the adverse effects of alcohol and THC. Alcohol alone caused mean SDLP to rise by 2.2 cm over the placebo level. Separate doses of 100 and 200 .g/kg caused mean SDLP to rise by 2.7 and 3.5 cm respectively. Changes in mean RT and HSD roughly paralleled those in mean SDLP. These changes were well above those shown after the same doses in previous studies employing the same methodology (Robbe, 1994). In the latter studies it was concluded that THC given in doses up to 300 .g/kg has "slight" effects on driving performance. The results of the present studies now compel us to revise that conclusion. The present subjects showed impaired car-following performance after THC 100 .g/kg whereas the previous one were not impaired in doses up to 300 .g/kg. In the present study, road-tracking performance after 200 .g/kg was worse than after the performance after 300 .g/kg in the previous studies. We believe that these differences are attributable to the groups' respective experience with THC smoking. The present group was less experienced and probably had not developed the same behavioral tolerance as their predecessors. In the present study, the mean changes in SDLP from the placebo level after THC 100 and 200 .g/kg were somewhat higher than those previously observed for BAC=0.05 g/dl (Louwerens et al, 1987), the legal limit in most European countries. The effects of THC in this study were thus not blatantly dangerous, but they were certainly more than slight. They were of sufficient magnitude to warrant concern. Drivers suffering the same degree of impairment as the present subjects did after THC alone would pose higher than normal risks to traffic safety.

The effects of combined alcohol and THC on the present subject's road tracking performance were severe. Alcohol plus THC 100 and 200 .g/kg respectively elevated mean SDLP by 5.3 and 8.5 cm. Relative to a previously established alcohol calibration curve (Louwerens et al, 1987), these changes were equivalent to driving with BAC=0.09 and 0.14 g/dl, respectively. Car-following performance was worst after the combination of alcohol and THC 200 .g/kg. Mean RT did not differ significantly after drug and placebo treatments, except in the worst case. The difference due to the combined effect of alcohol and THC 200 .g/kg was 1.6 sec. Since the average speed in that condition was about 97 km/h, this delay meant that the vehicle traveled, on the average, an additional 42 m beyond the point were the subject began to decelerate after placebo treatment. The drugs' effect on SDH was clearer: that parameter was significantly affected by every drug treatment. The changes in mean SDH reveal another adverse drug effect on driving: i.e., diminished ability to perceive changes in relative velocities of other vehicles and/or diminished ability to adjust one's own vehicle's speed accordingly.

The effects of combined alcohol and THC 100 .g/kg on city driving performance were also potentially dangerous. That combination reduced the mean search frequency for traffic at intersection by about 3%. The central driving task as measured by the driving instructor's rating of driving proficiency, was unaffected by THC plus alcohol. Apparently subjects were less able to detect peripheral traffic while trying to effectively perform the central driving task. They were not able to divide their attention equally over both subtasks, but focussed on the central driving task instead. This is not due to a direct effect of the drugs on the peripheral task itself, but is due to the focus on the central task. In the actual driving situation of the present study for example, the constant demand for the ongoing central driving task may overshadow the intermittent demands of the peripheral search task, particularly in the presence of drugs.

No unequivocal evidence emerged from the present study to indicate that interaction of alcohol and THC is synergistic. However the exponential rise in TOL from conditions where THC and alcohol were given separately to those were they acted in combination suggests that the interaction can increase the risk of certain types of crashes in the same manner. Drivers suffering the same degrees of impairment as the present subjects did after THC and alcohol combined would be exceedingly dangerous. Their impairment would be a serious threat to their own safety, and perhaps to the general driving public as well. The simultaneous consumption of low doses of alcohol and THC rendered the present subjects incapable of safe driving for several hours thereafter. That they were able to safely demonstrate their impairment was, on occasion, only possible because of the instructor's intervention. Had these individuals attempted to drive alone in that condition, it is quite possible that one or more would have caused a collision.

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