Cannabis and Alcohol: Effects on Closed-Course Driving Behaviour

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INTRODUCTION

This study investigated the effects of drug treatments upon the subject’s perceptual and decision making abilities and concurrent use of vehicle controls in a closed-course driving situation. The driving task is perceived as requiring two classes of behaviour. One involves the guidance of the vehicle based upon procedures of search, identification and prediction of environmental events. The second class of behaviour is concerned with the control of the vehicle involving decision making and the execution of the control movements.

Previous research investigating vehicle control patterns has discriminated between different road conditions, drivers with differing levels of driving experience and drivers with different accident and violation records. The effects of alcohol and cannabis on control use have also been investigated with varying results. In many instances the studies emphasised one aspect of the driving task to the exclusion of others regardless of whether control use was measured in a simulator or an instrumented car. Examinations of driving performance in a closed-course situation have been limited in many earlier studies by a drastic over-simplification of the driving task due largely to the practical difficulties of monitoring performance, and by the low speeds and short time periods involved in the testing situation.

While the normal hazards impeding safe travel on the road were absent from our experimental set up, responses in the various tasks involved the same procedures of search, identification and prediction of events as are required in traffic, so that the drivers’ use of vehicle controls was being monitored in a realistic driving situation.

METHOD

Driving Tasks

The course provided a varied tracking task and allowed for high speed driving down the straight portion of the track. Each circuit was 3.68 kilometres in length and each testing session comprised eight circuits of the track and lasted about thirty-five minutes. On each circuit the subject was required to perform an overtaking manoeuvre: he was asked to decide which was the last possible safe moment to pull out and overtake a lead car in order to return to the left lane by a target area marked on the roadway.

At the end of the straight portion of the track on which the overtaking manoeuvre took place the subject was warned by a road sign of a hairpin bend and requested to change down in order to negotiate this corner.

Following the hairpin bend subjects were requested by a further road sign to maintain a speed of 50 km/h and during this portion of the track, on six of the eight circuits, the subject received auditory signals over the headset he was wearing and was required to respond verbally as quickly as possible.

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The driver was then required to negotiate a gap the width of which varied over a range from no clearance to 0.5 metre wider than the car. A white line 60 m before the gap marked the point at which the driver began to slow down to speeds which he considered appropriate for the negotiation of the gaps. Once through or around the gap the subjects passed two road signs each displaying five place names of Maori origin. Each of the two sets of signs had a different target word to which the subject responded using the indicator lever as soon as he was sure that the target word was present. A set of traffic signals was manually operated to present four changes to amber and then red, and one of red to green. A derestriction sign marked the end of the 50 km/h limit and the driver approached the stop sign to begin the circuit again.

**Data Collection**

Analogue recordings of the movement of the brake pedal, accelerator, and steering wheel, and the speed of the vehicle were frequency modulated and stored on the sound channel of a portable video tape recorder. This provided a record of the use of the controls which was synchronised with a visual recording of the roadway taken from a position to the left of the driver's head.

**Procedure**

Each subject attended on four days with at least one day between each drug session. He was asked to abstain from any drugs on the day preceding the session and to eat a standard light breakfast on the testing days.

On Day One the subject drove the instrumented vehicle to the motor racing track 65 km from Auckland. This allowed him to become quite familiar with the vehicle. Once at the track the subject drove the experimental circuits accompanied by the experimenter on the first four circuits and then completed a further eight circuits alone.

In order to maintain a placebo effect the subject was told that his performance after consuming alcohol and marihuana was to be compared to this baseline session. In fact, the aim of this session, combined with the counter-balancing of treatments was to prevent practice effects obscuring the treatment effects.

The performance of each subject was compared after six treatments administered during the subsequent three sessions. On each experimental day the subject drove the research car to the track, and performed two reminder circuits. He then consumed two drinks and a cigarette, drove eight circuits, repeated the procedure and was taken home.

Thirteen subjects were tested. A modified latin square design was used for treatment administration with the two subjects in five of the drug orders and three in the remaining order.

**Drug Treatments**

Session 1 First administration: Alcohol Only (AO) — alcohol (dose adjusted for body weight) aiming to reach a BAL of 100mg% plus a placebo cigarette.

Second administration: Alcohol followed by Marihuana (AM) — placebo drinks plus 500 mg cannabis plant material.

Session 2 First administration: Placebo (PL) — placebo drinks and a placebo cigarette.

Second administration: Marihuana Only (MO) — placebo drinks plus 500 mg cannabis.

Session 3 First administration: Low Combined (LC) — half of alcohol dose given in AO, plus 250 mg active cannabis.
Second administration: High Combined (HC) — half of AO alcohol dose plus 250 mg active cannabis.

The subject was given thirty minutes in which to consume the two drinks and smoked the cigarette during the second fifteen minutes of this interval holding each inhalation for 10–15 seconds. The two strengths of cigarette contained 3.12 mg and 6.25 mg Δ⁹ THC respectively and minimal CBD and CBN. The placebo was plant material from which the THC was extracted but retaining the smell and taste of the active material. Alcohol levels were measured using an Alcolmeter, a portable breath analysis machine. Driving began thirty minutes after both drugs were consumed. The subject’s ratings of his level of intoxication and driving capability were collected before and after each session.

Subject Sample

All the subjects were male volunteers, contacted informally, who signed an indemnity form concerning the administration of alcohol and cannabis. The subjects were between the ages of 20 to 30 years. Average years of regular driving were 8.2, range 5–14 years. The group average for moving violations was 1.8 with a range of 0 to 8. The mean number of accidents was also 1.8 with a range of 0 to 4.

All subjects admitted driving on the road after smoking cannabis and after combining alcohol and cannabis use. The average regularity of driving after drinking was ‘about once every two weeks’, after smoking cannabis ‘once or twice a week’, and after combining both drugs ‘about once every two weeks’.

All subjects were employed and seven of the thirteen had some tertiary education.

RESULTS

Vehicle Control

The use of the vehicle controls by our subjects showed clear evidence of treatment effects despite large between-subject differences. The most marked were alcohol related effects on steering control. There was a significant decrease in fine steering wheel movements following AO and the three combined doses (see Table I). This reduction in fine steering wheel movement was present in the records of two thirds of the subjects in LC, HC and AO.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero crosses</td>
<td>p &lt;0.001</td>
</tr>
<tr>
<td>0°–3°</td>
<td>25.6 16.7** 16.8** 21.8* 19.7** 24.7 p &lt;0.001</td>
</tr>
<tr>
<td>3°–6°</td>
<td>9.9 7.2* 8.1 8.0 9.8 10.0 p &lt;0.001</td>
</tr>
<tr>
<td>9°–24°</td>
<td>22.7 22.3 23.7 22.2 23.3 20.9* p &lt;0.001</td>
</tr>
</tbody>
</table>

The only significant MO versus placebo difference was a decrease in coarse steering wheel activity. Eight of the thirteen subjects increased the number of 9°–24° movements in AO but the difference from placebo was not significant.

A shift towards coarser steering wheel movement may be related to utilisation of a different cue structure to control vehicle placement on the road.¹⁴ Alternatively, reduction of these fine steering movements which are not sufficient to change the direction of the car and which increase with task difficulty, may be a measure of the driver’s control effort.¹² The present finding of a decrease in such fine steering movements when the objective task.
constraints remained the same suggest that the subjects lowered their performance criteria following certain drug administrations.

That this lowering of criteria was at the expense of steering performance is indicated by the measures of lateral placement which were taken from the visual recording at two separate areas on the track.

**TABLE II Standard deviations of vehicle position on two portions of the track.**

<table>
<thead>
<tr>
<th></th>
<th>PL</th>
<th>LC</th>
<th>HC</th>
<th>AM</th>
<th>AO</th>
<th>MO</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approaching Hairpin</td>
<td>3.2</td>
<td>3.7</td>
<td>3.5</td>
<td>4.1*</td>
<td>3.8</td>
<td>3.3</td>
<td>p &lt; 0.005</td>
</tr>
<tr>
<td>50 km/h Section</td>
<td>2.2</td>
<td>2.9</td>
<td>2.7</td>
<td>2.9</td>
<td>3.0*</td>
<td>2.6</td>
<td>p &lt; 0.005</td>
</tr>
</tbody>
</table>

* p < 0.05 Scheffé Drug vs. Placebo

These results show an increase in the deviations of the vehicle’s path in the treatment conditions involving alcohol. This supports previous findings of simulator studies in which moderate doses of alcohol increased tracking error measures.3,14, 15 The significant increase in ‘wobble’ on the straight in the AM condition may indicate the importance of the elimination phase of alcohol intoxication for this performance measure as suggested by Mortimer and Sturgis.14

In neither set of measures did marihuana alone significantly increase the variability of the vehicle’s path. Once again, this finding is in agreement with simulator studies which have indicated no effect of doses of up to 15 mg Δ⁹ THC on pursuit tracking performance.16

**Speed control and decision making**

The speed at which the vehicle was driven was monitored throughout the session. There was a consistent tendency for speeds to be significantly faster during the AO and LC treatment sessions and to be slower during MO (see Figure 1).

A significant treatment effect on the speed of the vehicle travelling on the straight following the overtaking manoeuvre was found (p < 0.001) and group mean increases following LC and AO treatments of 6 and 8 km/h respectively were significantly different from placebo (p < 0.05). During the MO condition the subjects significantly decreased their speed by an average of 5 km/h.

The speed of the subjects’ return to base after eight circuits were completed was also monitored in an attempt to assess any effect of the ‘test’ situation on speed. On this circuit the increase in speed relative to the placebo condition in the LC and AO condition rose to 13 km/h.

The speed with which the vehicle was driven around the hairpin bend also showed a significant increase for AO and the two simultaneous combination administrations and a significant decrease for MO.

A similar pattern of speed changes was recorded as subjects negotiated the gaps of varying widths. Again, there was a significant (p < 0.05) increase in the vehicle’s maximum speed through the gaps following AO, and again, a definite drop in the speed following MO. This was significantly (p < 0.001) slower than in the AO condition but not significantly different from Placebo.

Subjects were instructed to drive around the gap if they were not sure the car could be safely driven through. The numbers of gaps hit or refused following the different treatments are shown in Figure 2. The effect of the treatments was not statistically significant although the trend is for a greater number of refusals and fewer hits in the MO condition relative to other drug treatments.
There was also no significant treatment effect upon the number of failed overtaking manoeuvres or refusals to overtake. It appears that in the absence of any negative consequences for unsuccessful overtaking a large number of failures rather than refusals ensued. These failures were fairly evenly distributed across drug conditions and were most often the outcome of the trials involving the fastest, increasing speed of the lead car.

There was, however, a significant treatment effect on passing time from the subject's car pulling out to crossing the target line. Passing times in both the AM and AO conditions were significantly shorter than those of LC, HC and MO.

TABLE III  *Passing times and speed measures during the overtaking manoeuvre.*

<table>
<thead>
<tr>
<th>Treatments</th>
<th>PL</th>
<th>LC</th>
<th>HC</th>
<th>AM</th>
<th>AO</th>
<th>MO</th>
<th>Treatment Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passing Time (secs) (pull out to target line)</td>
<td>8.4</td>
<td>8.7</td>
<td>8.9</td>
<td>7.7</td>
<td>7.9</td>
<td>8.7</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Maximum Speed (kp/h)</td>
<td>80.1</td>
<td>86.4*</td>
<td>78.4</td>
<td>80.8</td>
<td>84.3*</td>
<td>77.0</td>
<td>p &lt; 0.001</td>
</tr>
</tbody>
</table>

*p < 0.05 Scheffé Drug vs. Placebo.
The results for the overtaking manoeuvre in MO, slightly increased passing distances and times, and low speeds suggest a fairly cautious overtaking pattern despite the high number of failed manoeuvres. Passing times were consistently increased in MO. Effects of the two simultaneous administrations on the overtaking manoeuvre were more variable. Four of the seven significant treatment effects on passing time in both LC and HC involved a decrease in the time allowed.

**Reaction times**

The reaction times to the auditory signals showed significant increases ($p < 0.01$) following the three treatments involving the high dose of marihuana (see Figure 3). Responses following AO and LC were slowed but not significantly so. Alcohol related impairment in a divided attention situation such as this one depends upon the focus of attention of the subject. The effects on tracking and steering wheel movement found in AO and LC at the time the signals were likely to occur suggests that subjects may have been attending to the auditory task to the detriment of vehicle control.

![Figure 2](image)

**Figure 2** Speed when negotiating gaps.

There is a similar indication in the finding of a significant slowing of response following AO ($p < 0.05$) in the more difficult of the two visual recognition tasks which was placed just beyond the gap negotiation, when more attention to vehicle control was presumably necessary.
TABLE IV  **Distance from sign at which correct recognition was made.**

<table>
<thead>
<tr>
<th></th>
<th>PL</th>
<th>LC</th>
<th>HC</th>
<th>AM</th>
<th>AO</th>
<th>MO</th>
<th>Treatment Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5 letter sign</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean distance (metres)</td>
<td>59</td>
<td>56</td>
<td>55</td>
<td>55</td>
<td>57</td>
<td>54</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>Within subject variance</td>
<td>4.3</td>
<td>9.5*</td>
<td>6.2</td>
<td>8.1</td>
<td>6.5</td>
<td>9.5</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td><strong>7 letter sign</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean distance (metres)</td>
<td>42</td>
<td>43</td>
<td>39</td>
<td>39</td>
<td>37*</td>
<td>38</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>Within subject variance</td>
<td>6.9</td>
<td>7.6</td>
<td>8.4</td>
<td>7.1</td>
<td>8.0</td>
<td>7.4</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

* p < 0.05 Scheffé Drug vs. Placebo comparison using treatment minus baseline scores.
* ' p < 0.05 Multiple comparison Test Drug vs. Placebo.

There was a non-significant trend of slower response to both signs following MO.

![Figure 3](image)

**Auditory reaction times (msec).**

**DISCUSSION**

Driving in many traffic conditions is a self-paced task. The individual's driving behaviour depends upon a match between perceived risk and the amount of risk or emotional tension he or she is prepared to tolerate. It appears from the present results that the drug treatments administered may have had different effects upon performance measures indicative of the drivers' perception or tolerance of risk.

The pattern of driving following MO of control use similar to that following Placebo treatment and of consistently slower speeds suggests that in a self paced driving task such as this, drivers compensate for what they perceive as adverse effects on driving ability by...
maintenance of control effort and perhaps attempting to reduce the rate of required information processing by driving more slowly.

By contrast, the alcohol related speed increases and changes in steering control provides confirmation of the disinhibitory effect on driving performance already indicated by epidemiological studies of alcohol and road accidents.

There were several indications that performance under the combined effects of the two drugs was affected detrimentally by both. The combination of alcohol to induce a BAL of 50 mg% with 4.5 mg of Δ⁹ THC induced a pattern of speed increases and steering control that paralleled the effects of BALs of 100 mg%. The subjects as a group predicted the effects of this treatment on driving would be similar to those induced by BALs of 100 mg% and both of these were seen as less impairing than the effects of the two high combination doses and MO.

The two high combination treatments while resulting in the slowing of response time to the auditory task characteristic of the MO session also resulted in increased speeds and changes in vehicle control.

These combination effects suggest the potential for increased accident risk if social use of the two drugs simultaneously increases. In this regard it is interesting to note that in one study of accident involved drivers 70% of those admitting marihuana use prior to the focal accident had also used alcohol. In a further North American survey of marihuana users who were also drivers almost 70% had combined the use of alcohol and marihuana before driving.

The present findings are in agreement with previous estimates of the relative potential for accident potentiation of alcohol and marihuana. They provide evidence of changes in driving behaviour following simultaneous use of the two drugs which suggests the need for countermeasures before the pattern of combined use becomes more widespread.

REFERENCES


