Effects of Cannabis on Psychomotor Skills and Driving Performance - a Metaanalysis of Experimental Studies

G Berghaus, N Scheer, P Schmidt

Institute of Forensic Medicine, University of Cologne, Melatengürtel 60, 50832 Cologne, Germany

ABSTRACT

Taking part in road traffic under the influence of drugs, especially marijuana, has become a serious problem in most western societies. Thus traffic medicine is demanded to provide scientific knowledge of the effects of cannabinoids on driving performance. The present study is intended to analyse all available data on the influence of cannabinoids on psychomotor skills relevant to driving behaviour using a metaanalytic approach. About 150 experimental studies including laboratory, driving simulator and on road experiments make up the basis of our investigation. With the help of a systematic questionnaire the most important information extracted were: number, age, sex and user behaviour of the subjects, manner of drug treatment, time between drug intake and testing, tasks presented and the experimental findings concerning the drug effects. Subsequently the data were examined by the means of interferential statistics. For the first time a methodological approach is applied enabling to establish detailed statements on kind, intensity and duration of drug impairment dependent on dose, user behaviour, treatment and further variables.

INTRODUCTION

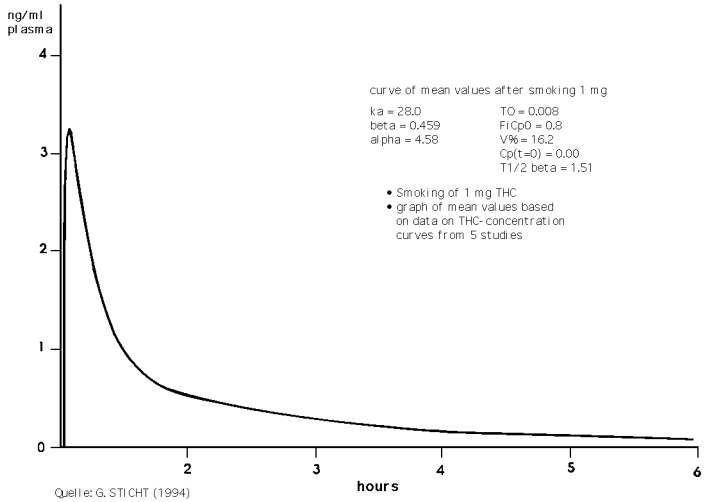
Up to now more than 120 experimental studies on the THC-effects connected with the ability to drive a vehicle safely have been published. Different aspects of the subject have been investigated applying a large variety of experimental designs and approaches to record driving ability. Every attempt at reviewing the available knowledge must remain incomplete without systematic extraction of the experimental data from the publications. Furthermore only few investigations provide analytical data of THC-concentrations in plasma at the time of testing so that it has been impossible to establish a correlation with the effects on performance.

To cope with these shortcomings we have systematically analysed the essential information of the published studies applying a metaanalytic approach. In addition the THC-concentration at the time of testing was calculated with the help of a standard curve and was included in our analysis. Due to this for the first time detailed results on the kind and intensity of THC-effects on performance may be shown in dependency on the THC-concentration. Furthermore controversial results of the single experimental studies are expected to be balanced out so that a more uniform tendency will emerge.

MATERIAL AND METHODS

The analysis presented is based on published experimental investigations testing at least one effect of THC connected with the ability of safely driving a vehicle. More than 120 papers were collected by computer searches in relevant databases and by checking the references in the processed literature. From papers meeting defined quality criteria the essential information was systematically extracted including aspects of the methods applied, sample size, age, number and user behavior of the subjects, applied THC-dose, time interval between the beginning of THC-intake and testing, testing procedures and performance of the subjects. In comparison with placebo, respectively a control group the results of the tests were categorized as "significantly deteriorated", "no significant effect" or "significantly improved" on condition that the type 1 error was less than 5 percent. The observables were aggregated into broader classes according to Krüger et al. (1990). To elucidate a possible relationship between the THC-concentration and the extent of impairment several studies on the pharmakokinetics of THC were taken to establish a graph of mean values (Sticht, 1994). With the help of this graph (Figure 1) the respective THC plasma concentrations at the beginning of each test were calculated from the dose administered and were included in the data set serving as the base for our analysis.

Figure 1
THC Concentration Curve



RESULTS

From the 120 experimental studies encountered in literature 60 fulfilled the inclusion criteria of this review and make up the basic material of the analysis. A total of 1344 findings of effects (such as reaction time, results of decoding tasks etc.) are recorded. Table 1 shows the main characteristics of the 324 experiments included in the 60 studies. Young males with varying user behavior who smoked THC account for the majority of the subjects.

The median of the THC-dose administered was 10.7 mg. Most tests were carried out a relatively short time after the intake of the drug. Longer intervals between the application of THC and the beginning of the tests were mainly chosen following oral administration.

Table 1
Characteristics of the 324 Experiments

age of subjects	median of 25 years / 18-59 years
sex of subjects	74.4% without females 2.5% without males
THC-application	71% smoke 29% oral
THC-dose	6.9 25-percentile 10.7 50-percentile 17.5 75-percentile
user behavior	4% no or infrequent use 7% up to 3x / month 35% 1-6x / week 4% 1-2x / day 49% varying user behavior
time between the intake of THC and testing	44% up to 1 hour 67% up to 2 hours 76% up to 3 hours 86% up to 4 hours

This review concentrates on the effects of smoking marijuana because this way is preferred by most users. It is restricted to the performances measured., the subjective impressions of the consumer the mood, the social and aggressive behavior are left aside.

Table 2 is intended to give a first impression on the main effects -independant on the THC dosis smoked- on the various performance areas tested in dependency on the postsmoking interval. To start with the most important result: smoking of marijuana causes to a more or less obvious extent impairment of every performance area connected with the safe driving of a vehicle . Thus performance areas as tracking, psychomotor skills, reaction time, visual functions, attention, en-/decoding and performance in simulated or real drivingexperiments are involved. In each of these performance areas significant deterioration in dependency on the postsmoking interval - that is to say on the THC-concentration in plasma - is found after smoking marijuana. THC-related impairment is concentrated within the first two hours after the beginning of the smoking procedure. Attention, tracking and psychomotor skills reveal the highest percentage of significant deterioration.

One has to take into consideration that the results presented are additionally determinedby the different distributions of the doses applied and of the times of testing, i.e the concentrations in the different performance areas. We think that the statistical method of survival analysis provides an optimal tool to show the performance in dependency on the THC-concentration if the dimension ‘survival time’ is replaced by the dimension ‘survival

concentration' (concentration not yet causing a significant deterioration of performance). The x-axis of Figure 2 gives the THC-concentration. The upper graph represents the 'cumulated survival rate' showing the percentage of effect findings which is not yet significantly impaired due to a given concentration of THC. At the concentration 0 ng this graph of course starts at about 100 per cent because only few effect findings already show significant impairment. The graph descends from the very beginning on, that is to say even at low concentrations of THC impairment of performance was found in the respective experiments. The second graph may be characterized as the complement of the upper one and gives the cumulated probability which percentage of effect findings at a given concentration will be significantly deteriorated at the succeeding higher concentration.

Table 2
Effects in Dependence on the Postsmoking Interval

Performance	**Time after the beginning of smoking**							
area	≤ 20min	- 1h	- 2h	- 3h	- 4h	- 5h	≥ 5h	sum
tracking	**59**	**80**	**67**	**33**	25	**0**	-	60 81
psychomotor skills	**73**	**69**	100	66	**0**	-	-	58 40
reaction time	**75**	25	-	-	-	0	0	54 24
visual functions	**43**	0	**20**	-	0	0	**20**	26 43
attention	**76**	**73**	50	-	-	-	0	73 69
divided attention	**69**	**71**	-	-	-	-	0	68 66
en-, decoding	**74**	**34**	**30**	0	0	-	25	46 98
simulator driving	**46**	**65**	**33**	**33**	**54**	**20**	**42**	46 138
sum	65 239	59 149	42 66	36 22	26 31	6 17	31 35	54 559
number of studies	27	19	9	4	5	5	7	46

The figures give the percentage of significantly deteriorated observables (at the 5% level).
Bold typed figures based on more than 5 effects.
Small figures = total number of effects.

Figure 3 shows those areas of performance which - at a THC-concentration up to 16 ng/ml plasma - reveal distinct differences from the curve of all performance areas (bold curve). In the performance areas tracking and attention the percentage of significantly impaired effect findings obviously exceeds the average. The curve representing tracking illustrates a deterioration going beyond the curve of all performance areas beginning at a concentration of 4 ng, the curve representing attention beginning at a concentration of 9 ng. On the contrary, visual functions (physiology of the eye) and en-/decoding show a lower percentage of significantly impaired effect findings in comparison with total performance.

Figure 2
THC-Related Impairment

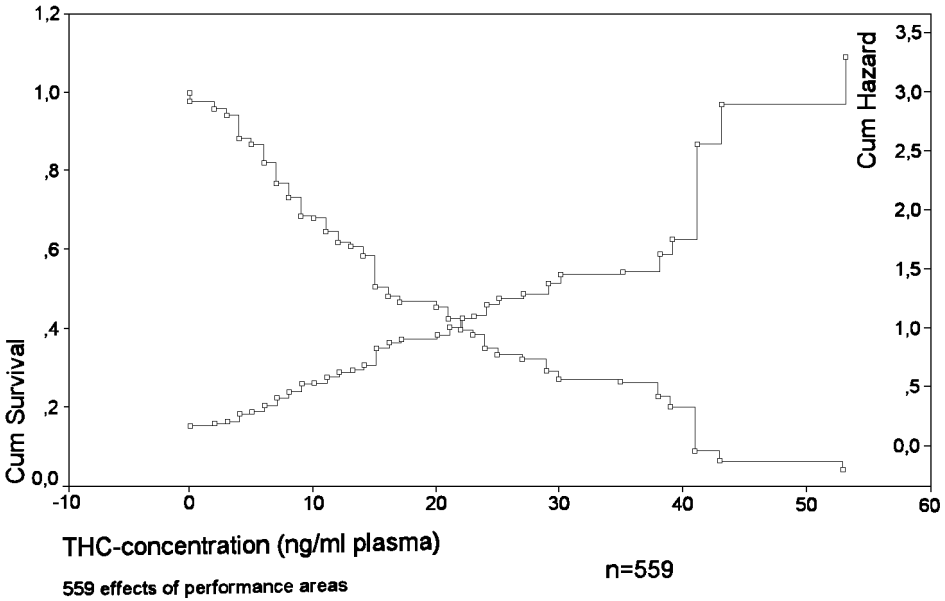
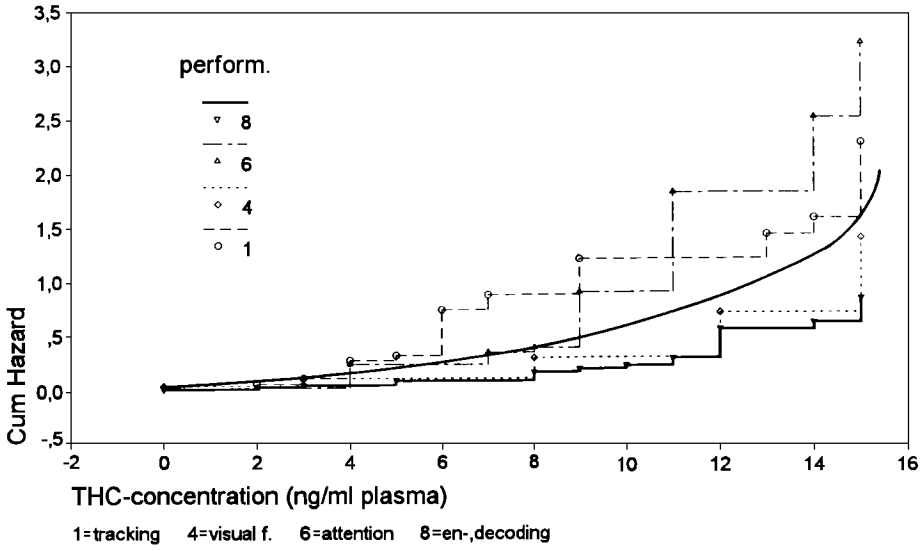


Figure 3
THC-Related Impairment



Quite interesting is that the extent of impairment indicated by the simulator and driving experiments is in good agreement with the average deterioration. One might have expected that the performance in the simulator, respectively driving experiments which may be considered as synopsis of all performance areas might be deteriorated exceeding the average because the impairment in the single performance areas displays a kind of additional effect. The fact that this addition of impairment was not observed points at the ability of the subjects to compensate THC-related deficits. These deficits which cannot be compensated in a laboratory experiment testing one distinct performance area due to the testing method may be balanced out in a simulator or real driving experiment by improved performance or greater caution in other performance areas.

Table 3 shows a subtly differentiated classification of the performance areas. With the help of the median (concentration of THC connected with 50% of the cumulated results being significantly negative) an order of rank is established with respect to the sensitivity for THC-related impairment. Tracking and psychomotor skills are already significantly impaired at low concentrations whilst deterioration of simulator and real driving experiments, en-/decoding and reaction time requires higher concentrations.

Table 3
Order of Rank of the Performance Areas
Indicating THC-related Impairment

Performance area	ng/ml plasma	number of effects
tracking	6	73
psychomotor skills	8	29
attention	9	44
divided attention	11	59
visual functions	12	25
simulator/driving	13	113
en-/decoding	15	63
reaction time	15	14
all performance areas	11	420

To sum up some further results of the metaanalysis:

- THC-related impairment predominates in the resorptive phase as compared to the elimination phase,
- frequent users reveal less impairment than unexperienced consumers,
- the higher the dose administered, the more obvious the impairment,
- the negative effects of cannabis are subjectively overestimated by the subjects; cannabis consumers are more able to compensate their deficits than alcohol consumers,
- the maximum high is achieved later than the maximum THC-concentration

- a subjective effect already occurs after 1 or 2 inhalations,
- the maximum of bioavailability is about 50 percent and depends amomg other factors on the dynamics of the smoking procedure: number, volume and interval of inhalations.
- some physiologic effects are: increase in heart rate, raise of blood pressure, dilation of the pupils and injection of the conjunctives,
- externally observable symptoms (for example impairment of psychomotor skills or the impression of absent-mindedness) quickly disappear during the early elimination phase.

DISCUSSION

The briefly reviewed results of the metaanalysis of experimental studies on THC-related deterioration of performance support many results which have already been suggested in the single studies. Going beyond the interpretations possible based on single studies the metaanalysis allows the creation of new hypotheses. Since the systematic extraction of information from single publications and the subsequent analysis of results in dependency on the THC-concentrations was carried out using the same technique as used by Krüger et al.(1990) it is possible for the first time to compare experimental results after alcohol and cannabis intake (Krüger and Berghaus, this volume).

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